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NEUROLOGICAL SURGERY, SO TO SPEAK, OUT OF ROENTGENOLOGY

HICKEY LECTURE, 1956*

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THERE are few men endowed with the habits of close observation and study, who are masters of detail and are respecters of experience, who, at the same time, preserve an undiminished flexibility of mind, have a genius for friendship, are companionable, tolerant, unselfish and possess a kindly patience. It is, I believe, these personal characteristics which shape the lasting effect which such individuals make upon their chosen field in medicine. There have been, and can be, only a few whose names endure because of a contribution which revolutionizes the practice of our profession. Those others, of whom I speak, by their precepts establish a continuing chain reaction because they have influenced their colleagues.

Starting with a small chemical laboratory, which his pioneer missionary father allowed him to have in his home as a boy, it seems natural that Preston Manasseh Hickey should have become a professor of pathology and a specialist in diseases of the throat and respiratory tract at the age of thirty-one, when Röntgen made his discovery. It is unnecessary to refer in detail to the contributions to radiology for which his ability as a technical perfectionist was responsible. His organizing talents, his frankness and modesty were responsible for this Society and others; the favorite nickname by which he was known among you testifies more eloquently than words to the high regard in which he was held.

It would be my opinion that he might well be compared to Weelum McLure, Ian MacLaren's Doctor of the Old School; he taught the science of roentgenology, the art of dealing with patients, the method of living with his fellow men thus gaining their respect and love, and the ability to develop cultural and spiritual attainments in the process.

I have been honored to be chosen to join the list of distinguished men who have given this lecture dedicated to the memory of Preston Manasseh Hickey.

There is an added pleasure in the opportunity given me to recount the gradual

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collaboration between Roentgenology, its allied sciences and Neurological Surgery because my professional life has encompassed the interval between the glass plate used to record the presence of the assassin's bullet in Theodore Roosevelt's chest to the rapidly recording roentgen-ray camera which produces multiple angiograms. During this time, my association has been with my surgical chief who was among those pioneers who did not know the strange power of those unfelt and invisible rays which diagnose, cure and destroy and who had multiple operations upon his hands to remove roentgen-ray induced cancer, and others distinguished in your specialty.

As a student, in 1914, it appeared that the graduate nurse who roentgenized the patients, and by experience alone became financially secure, successful, and as a result more and more confident in her diagnostic abilities, had opened another field for the nursing profession. It was said, of course, that a degree in nursing was a prerequisite for a roentgenologist. But, on the other hand, it was apparent that a well-known and successful surgeon, who filled Mercy Hospital in Chicago with his patients, had encouraged a former hospital orderly to invest in a roentgen-ray machine and rent laboratory space from the hospital. It was this roentgen-ray technician, who made the glass plate picture which localized Roosevelt's bullet and it was that case which strengthened the surgical principle of not probing for the bullet.

Soon, however, Edward Blaine appeared at Wesley Memorial Hospital and James Case made regular commutations from Battle Creek to teach Northwestern students that the gamma rays of radium are the same as the rays of Röntgen; that a new domain in physics and chemistry had been opened along with new chemical affinities and new principles in electricity, light, gravitation and energy. My association with the former, as a surgical trainee, was characterized by a patience, kindness and willingness to encourage a young man which has never been forgotten. It extended to tolerating the muss, confusion and expenditure of supplies engendered in the young man's efforts to fill the ventricles of fixed brains with liquid mercury, then roentgenographing the specimen, in an effort to establish the variations in size and conformation of the normal cerebral ventricular system. It was at that time that Dandy had been imaginative enough to inject air into a patient's lumbar subarachnoid space in such a large quantity that it outlined the cerebral and basilar subarachnoid spaces and the ventricular system. The frequent failure of the spinal pneumoencephalogram to outline completely the ventricular cavities was met by the injection of the air directly into the ventricles through ventricular cannulas.

As with all new procedures of a diagnostic nature, these methods were met with skepticism, with the charge that the ventricular cavities were being pumped full of air, and that no such new-fangled surgical exercises could replace the art of clinical neurological examinations. At the Peter Bent Brigham Hospital, there may have been possibly the added resistance to accepting the pupil's ideas to improve the diagnosis of intracranial space occupying lesions by his surgical teacher. It was at this period in my own neurosurgical learning that I came to look upon one of your distinguished members as a friend, who realized the difficulties a mid-westerner might encounter in his post as a voluntary assistant on the service of the master neurological surgeon, in a charming hospital in staid Boston. I seriously doubt that Lawrence Reynolds is aware of the kindness and friendliness which he exhibited and which I have treasured through the years.

Through the years, pneumoencephalography has become an accepted daily neurosurgical diagnostic procedure which requires the closely coordinated efforts of the surgeon and the roentgenologist. Now, the shock, pain and inherent dangers of spinal encephalography and the less disturbing ventriculography, which nevertheless requires a meticulously performed surgical

procedure, are fast disappearing through the use of fractional pneumoencephalography which utilizes 15 to 30 cc. of air injected into the spinal subarachnoid space, without the withdrawal of fluid, and which obviates much of the suffering and dangers of the original methods. It must be pointed out, however, that the time required of the roentgenologist, the number of films which are necessary, and the skill employed in filling each component of the ventricular and subarachnoid system are considerable. The success of the method is a further contribution to the progress made by the roentgenologist and neurological surgeon in their cooperative efforts to aid their patients.

This cooperation is necessary and desirable; certainly, the surgeon cannot do without the roentgenologist and I am of the firm opinion that the roentgenologist must not accept the responsibility for the possible necessity of an immediate craniotomy. Through the years, various experiments have been carried out with different gases, such as oxygen and helium, but it has been our experience that the introduction of air has been quite satisfactory, and has not prolonged the postinjection absorption period nor increased the immediate headaches. There are some neurological surgeons who follow pneumoencephalography immediately with the surgical procedure as a matter of choice. If the clinical situation appears to demand aid from pneumoencephalography or ventriculography, immediate surgical intervention is usually unnecessary. It is my opinion that in most instances when immediate operation is necessary, a carefully and repeatedly performed neurological examination will lateralize and so localize the lesion that little surgical aid will be forthcoming from air studies.

It has become an axiom that spinal pneumoencephalography should never be attempted in the presence of a papilledema. This, undoubtedly, followed the experiences of fatalities ensuing upon a spinal puncture in the presence of a space-occupying lesion in the posterior fossa. The reduction of intracranial pressure may cause a herniation of the cerebellar tonsils into the spinal canal with compression of the medulla. This contraindication to a spinal puncture still holds, but the situation is different in the presence of a supratentorial space-occupying lesion and the use of a small amount of air with fractional pneumoencephalography.

The contribution of this combined roentgenological and surgical diagnostic method to the advancement of neurological surgery has been invaluable. The accuracy of the diagnoses has been high, but the discomfort and pain suffered by the patient and the dangers inherent in changing the intracranial hydrodynamics relatively abruptly led to the search for other diagnostic methods which might be comparable, if not more accurate.

In the meantime, attention was called to the shift of the calcification in the pineal gland, when it was identifiable, in the presence of space-occupying lesions. Roentgenologists were becoming more and more familiar with the changes in the bone of the skull produced by meningiomas, pituitary adenomas, and acoustic neurinomas as they were verified by the neurological surgeon. At the same time, Cushing's large series of verified intracranial tumors provided the data upon which was based the frequency of the occurrence of calcification in the gliomas, craniopharyngiomas and various vascular tumors. Rather seldom did the roentgenologist find the evidence of metastatic tumors in the bones of the skull, but the neurological surgeon and the pathologist found that many of the metastatic tumors of the brain had their origin in small, often microscopic, tumors originating in the lung. So, it has become routine for every patient, suspected of having an intracranial space-occupying lesion, to have a chest roentgenogram.

It required almost as long for the procedure of angiography to become an accepted, commonplace, diagnostic aid in the verification of the clinical diagnosis of an intracranial aneurysm, or arteriovenous fistula, in the demonstration of vascular

patterns in angiomatous tumors, in the displacement of the normal position of the branches of the internal carotid artery, in the presence of comparatively silent tumors of the frontal lobes, and in the visualization of a thrombosis of the internal carotid artery in patients previously diagnosed as having a "stroke."

This is a technical method which can fail miserably because of the complicated, mechanical apparatus of the roentgenologist, or because of the awkwardness of the surgeon in introducing a needle through the skin into the carotid artery. We have gone through the period of exposing the carotid artery in the operating room, moving the table and the patient to the roentgenographic room, only to have the proper synchronization of events never take place. At that time, it was difficult to understand why an arteriovenous fistula did not develop between the common carotid artery and internal jugular vein, since the latter almost invariably lies to some degree over the artery and the needle passes through it first before entering the artery. Again, the multiplication of experiences demonstrated that such was not the case, and so my younger associates developed the facility of injecting diodrast percutaneously into the common carotid, after 50 mg. of thorazine had been given to counteract the possibilities of vascular spasm, and such respiratory complications which may occur with the injection.

Concomitantly, one of my colleagues constructed a simple wooden film cassette which has made it unnecessary to struggle with the vagaries of a costly, large complicated, multiple exposure camera. We are able to demonstrate capillary and venous phases, in addition to the usual lateral and anteroposterior views of the cerebral circulation, with satisfactory regularity. Now, intracranial aneurysms are verified roentgenologically before ligating the common carotid artery, even though in the majority of patients the clinical neurological findings are sufficient to make the diagnosis and indicate the surgical procedure. The number of times it is desirable to inject the vertebral artery is few, particularly since it has been shown that the supply of the vertebrals can be demonstrated easily by employing a reflex technique while injecting the more accessible common carotid.

We have not been impressed by patterns of blood vessel distribution in intracranial tumors, except in the angiomas, cortical arteriovenous fistulas, and possibly the meningiomas. In the former, the information received is invaluable; in the latter, it is only confirmatory of other more easily interpreted changes in the bone. As to patterns typical of gliomas, we cannot subscribe. Frequently, we have made the diagnosis of a space-occupying lesion, when pneumoencephalography was not helpful, by the displacement of the anterior cerebral artery to the opposite side, or by a change in the conformation of the middle cerebral artery as it normally and gracefully turns backward.

As the Consultant in Neurological Surgery to the European Theatre of Operations in World War II, it became evident to me that the number of soldiers complaining of backache, after injuries of varying degrees of severity, was rapidly becoming a problem. Among them were those with severe pain radiating down the distribution of the sciatic nerve in the leg. Perhaps because Mixter, a neurological surgeon, and Barr, an orthopedic surgeon, called attention to the sciatic syndrome, the problem of the herniated nucleus pulposus became one of contention as to jurisdictional rights, a subject about which I believe the citizens of Michigan have some first hand knowledge in other pursuits.

As often happens in medicine and surgery, terms became confused and even laymen began to speak of a "slipped disk." The facts of the matter are that usually, as the result of injury, the annulus fibrosus of the intervertebral disk becomes weakened laterally and the nucleus pulposus, the functionless remnant of the embryologic notachord, herniates toward that area. So, the nucleus pulposus pushes outward, or often

ruptures through the annulus, and impinges upon the nerve as it courses to the intervertebral foramen. It is as if the nerve were stretched as tightly as a string across the bridge of a violin. To cure the patient of his pain, sensory and motor symptoms, disabling posture and muscle spasm, the nerve must be decompressed. To fix the spine by fusion without decompressing the nerve does not permanently cure the patient. To decompress the nerve and at the same time fuse the spine usually results in what may easily occur when two surgeons attack a patient simultaneously. If the spinal column shows evidence of disease which requires its fusion, this indication then exists separately from the herniation of the nucleus pulposus and should be so treated, in our opinion.

All of this I speak of because the roentgenologists and the neurological surgeons in the European Theatre of Operations cooperated to use the new substance, known as pantopaque, which had been developed to replace lipiodol in the spinal subarachnoid space. Many of us are fundamentally opposed to the injection of substances into the cerebrospinal fluid based upon experimental investigations of the reactions thereby produced. But, as in all of medicine and surgery, one must weigh the disadvantages against the advantages to the patient, providing we are not using a shotgun to kill a sparrow. In fact, in many institutions today it is felt that air in myelography is preferable to pantopaque, even though it be removed immediately after the diagnostic procedure has been completed. There are those also who maintain that their clinical diagnostic acumen is accurate enough to dispense entirely with roentgenological demonstration of the filling defect produced by a herniated nucleus pulposus. However, in an experience with 1,154 patients with herniations in the lumbar area, we have not reached that plateau of accuracy.

Thus it was that our experience with myelography began. It is our custom to use 4 cc. of pantopaque injected into the subarachnoid space after the withdrawal of 5–10 cc. of cerebrospinal fluid which can be used for chemical analysis, and after a spinal manometric study has been done. The needle is always removed so that the roentgenologist and surgeon can have perfect freedom in moving the patient about during the fluoroscopic and film examinations. Further, we believe that the needle may cause a filling artefact. Again, this is a cooperative and consultative effort because the entire story is not always recorded on the film. The fluoroscopic evidence may be far more impressive.

The filling defect may be minimal, consisting only of a failure of a dural root sheath to fill and the clinical symptoms may be maximal. Or, the clinical findings may be minimal and the roentgenological evidence may be unquestionable. It is, however, the exchange of information, after surgical verification of the lesion, that improves our diagnostic accuracy. Such a procedure requires time and a mutual interest in the problem which, if I were the patient, I would desire.

Myelograms have provided surgical information of great value to the patient in the presence of a suspected spinal cord tumor. In the past, the presence of an incomplete or complete subarachnoid space block, a high total protein content of the spinal fluid, and neurological findings have sufficed for a surgical indication. However, there are many instances on record in which the surgical field was above or below the lesion, and in which the removal of more spines and laminae had to be done before the lesion could be identified. The demonstration of the exact lower level of the block in the spinal subarachnoid space by myelography has been an invaluable contribution to a meticulously performed laminectomy.

We do not subscribe so enthusiastically to the use of myelography in the cervical area of the spinal column. The anatomical structure of the cervical dural canal, the size of the cervical spinal cord, and the possibility of the entrance of the pantopaque

globules into the cerebral subarachnoid spaces make us hesitant to perform myelography in this area. This opinion is differed with by others, but the exactness of motor and sensory nerve root dysfunction in the cervical spinal cord, the comparative rarity of a cervical herniated nucleus pulposus, and the frequency of impingement upon a cervical nerve by an osteoarthritis which can be diagnosed plainly by a film of the cervical spinal column have influenced us to use myelography sparingly in these lesions.

The search for better methods of diagnosis in intracranial lesions continued and in our own laboratories, at the suggestion of Lewis Pollock, we attempted to inject fluorescein and detect its special affinity for tumor cells by using the ultraviolet rays. This was long before it was suspected that, as a result of atomic studies, a radioactive tracer dye test was within the realm of possibility. It was not until 1947 that Moore and his associates first used radioactive fluorescein as an agent in the differentiation of normal and neoplastic human tissues. In an initial report upon 15 patients, they demonstrated the clinical usefulness of iodine 131 labelled-fluorescein in the diagnosis and localization of brain tumors. Tabern then developed a method for the production of stable di-iodo-fluorescein which contained no free iodine 131, or other iodinated fluorescein compounds.

In 1949, my associates and I reported upon our experiences with the use of di-iodo-fluorescein in a group of normal patients and those suspected of having an intracranial tumor. As is often the case, either we did not express ourselves accurately, or those interested did not carefully read what we had written. Actually, the experience with this activated material in a large group of individuals was necessary to evaluate its possibilities. It was stated then that we had found it to be 95 per cent accurate; which is to say, that it indicated the presence of a space-occupying or other lesion, and did not give false indications in individuals who were apparently quite normal. However, in 1950 we again reported upon the use of the radioactive di-iodo-fluorescein test for the localization of intracranial lesions in 340 patients with a clinical diagnosis of a space-occupying lesion of the central nervous system; and again in 1953, after an experience with 1,251 patients.

In 1950, one of our neurosurgical residents in training had been of considerable aid in constructing a shielded Geiger tube connected through an amplifier to a general radio counting rate meter, so that the counts per minute were recorded on an Esterline-Angus milliammeter. The tube could be maintained at various fixed positions over the skull and readings of at least three minutes' duration were obtained over each site. A tracing was produced which could be transferred to an outline drawing of the skull. The most significant counting rates occur within one half to two hours after the intravenous administration of 1.1 millicuries of radioactive di-iodo-fluorescein. The technique, advantages, and limitations of the test were described in detail, in view of the relative simplicity, harmlessness and accuracy of the procedure.

It was our opinion that the affinity of the radiodye for tumor tissue is related not only to the degree of the cellularity of the tumor, but also to its vascular pattern. There is relatively little concentration of dye over the sites of large cysts. Localization with this method, in our hands, was more accurate than with electroencephalography, and if it proved as accurate as pneumography, we believed it to be a valuable addition to our diagnostic methods.

Since then we have had large experience in its use in the hands of a technician. Obviously, this was as necessary a refinement in the practical method of using the test as it is for there to be roentgenological technicians. If the tracings could not be interpreted by the surgeon, as are films by the roentgenologist, then the test would be quite impractical. We have found that this test is helpful; that it is painless and not disturbing to the patient; that it is more accurate than electroencephalography and

as accurate as pneumoencephalography. However, we believe that the present method of fractional pneumoencephalography is superior.

In gathering this experience with the radioactive dye test, we have used activated serum albumin, sodium iodide as well as di-iodo-fluorescein, but believe the latter to be the best tracer agent.

It was evident that the field of radioactive diagnostic and therapeutic procedures would inevitably increase and expand rapidly. It seemed to us that the logical individuals to become interested in new materials were men who by training and experience had an interest in biophysics and the influence of radioactive emanations upon the body, that is to say, the roentgenologists.

As refinements have progressed in the technical, diagnostic and operative procedures in the surgery of the nervous system, we have remained of the opinion that the most challenging field to the neurological surgeon is the treatment of intracranial tumors. I refer, in particular, to the treatment of the gliomas which constitute about 40 per cent of any large series of intracranial tumors. There are some areas of the brain in which block removal of a glioma can be performed without leaving the patient a hopeless socially and economically dependent invalid. The survival period in these patients compares very favorably with malignant tumors in other locations. However, other areas of the brain do not lend themselves to the comparatively gross procedures of our present surgical techniques. Naturally, neurological surgeons have cast hopeful eyes upon the employment of radium, radon seeds, roentgen rays, radioactive substances, and now hypersonic waves to destroy tumor cells, leaving intact normal brain structure.

We have exposed patients to the rays of radium applied externally, and we have introduced radon seeds into tumors and the cavities left by surgical attempts at removal. Our experiences were brief, but sufficiently clear to establish the opinion that radium, or radon seeds, offered no advantages whatever over the employment of roentgen rays.

Admittedly, the problem of evaluating the effect of roentgen rays delivered through the intact or decompressed skull to a glioma is difficult. From our laboratory, we have reported upon a comparison of the appearance of tumor cells before and after exposure to several thousand r units. There is no question from these microscopic studies of the effect of roentgen rays upon the tumor cells with sparing of the normal brain cells. The difficulty lies in the depth of penetration into the tumor which can be obtained without damage to the overlying scalp and the brain.

It is a difficult task to set up controlled clinical experiments between those individuals exposed and not exposed to postoperative radiation. Not all tumors, classified as the same, are exactly similar, and the patient's biological response to the tumor is never alike. One astrocytoma contains no detectable glioblast cells after careful search of the tumor material removed; another shows scattered glioblast cells. The former may have an excellent postoperative course for several years, only to develop a recurrence suddenly which requires a "second look." The tumor tissue removed may then be completely typical of a glioblastoma multiforme. In the second instance, the patient may go on rapidly to a fatality within a few months after the first operation. How difficult it is then to judge whether or not roentgen treatment in the first instance delayed the eventual clinical crisis. Postoperative follow-up examinations exist in our series of intracranial gliomas, verified by microscopic study which extend over 15–20 years with and without roentgen therapy.

On the other hand, the effect of roentgen rays upon pituitary adenomas and medulloblastomas, tumors of the primitive nerve cells which occur most commonly in children and in the posterior fossa, is unquestioned and has been proved by gross and microscopic studies. We have maintained

the position, however, that roentgen rays must not be used without previously exposing the tumor and verifying it, particularly if visual field changes are present in the case of the pituitary adenoma, and always in the instance of the medulloblastoma.

The question of whether or not high voltage roentgen rays are more effective than the ordinary therapy voltage rays has not been solved to our satisfaction. We are of the opinion, that no advantage exists in favor of the high voltage roentgen rays. It is our practice to deliver in the neighborhood of a total of 5,000 r units postoperatively through several portals extending over a period of 20 or more sessions. The question of the advisability of repeating this dose and, if so, when, is one which plagues me and my roentgenological colleagues.

Rather naturally with the advent of the radioactive substances, the question arose as to how they might be utilized in the treatment of intracranial tumors. Radioactive iodine has been employed for many years in the treatment of diseases of the thyroid gland; radioactive phosphorus (P^{32}) was used intravenously to treat leukemia; a method of distributing beta irradiation to the reticuloendothelial system and adjacent tissues by the intravenous use of a colloidal suspension of chromic phosphate has been described; and preparations of artificial radioactive isotopes in the colloidal form of yttrium, zirconium, columbium, lanthanum, silver and manganese dioxide have been used. Brues has stated that radioactive compounds injected systemically must exhibit an affinity for malignant tumors by a factor of 100 or more above the total body concentration to be ideally effective. Probably no substance exhibits this affinity.

Therefore, radioactive compounds were injected interstitially. A colloidal suspension of radioactive gold injected into tumor tissue remains fixed at the site of injection, but 50 per cent of the beta particles from gold travel about 3.8 mm. in tissue; thus, its effect is confined to the structures infiltrated or those immediately adjacent.

Our laboratory was the first to investigate experimentally the effect of radioactive gold upon normal brain tissue. To combat the difficulty of the inability of friable tissue to hold the fluid which contains the radioactive substance after injection, it seemed logical to us to line the bed from which an intracranial tumor had been removed with an absorptive substance, such as gelfoam, which had been impregnated with radioactive colloid in an attempt to irradiate the tumor cells which had been left behind. We have worked with radioactive gold and, in patients, with radioactive chromic phosphate.

Using Chamberlain's formula for the topical application of radioisotopes, and applying it to P^{32} using approximately 90 microcuries per square centimeter, we believed we could deliver 384,000 equivalent roentgens at the surface of the tissue. Beyond 1 mm. approximately 200,000 equivalent roentgens would be delivered, while below 2.2 mm. approximately 38,000 equivalent roentgens would be effective. Below 4.8 mm. approximately 3,800 equivalent roentgens would be delivered and there would be practically no destruction of tissue beyond 6.9 mm. We have had an experience with about 30 patients in whom we have left gelfoam impregnated with radioactive disodium phosphate in the bed of the cavity after surgical removal of tumor tissue. We have also employed the Geiger surgical probe counter to attempt to judge the completeness of the removal of tumor tissue. Thus far, our results are no better than those obtained with the roentgen rays, but again, a large series of patients followed over a long period of time with correlation between the type of tumor and the biological response of the patient is necessary to form a conclusion.

This is a problem which the neurological surgeon must consider his foremost challenge. To ignore the treatment of intracranial tumors, or to adopt a completely

defeatist attitude toward their treatment, is unworthy of one who regards himself as a neurological surgeon. Admittedly, the problem is complex; the results thus far can easily discourage the fainthearted, but otherwise I believe I may inquire logically, why the field of neurological surgery?

However, the neurological surgeon requires the interest and the cooperative efforts of the roentgenologist to whom I believe this exciting and enormous field of radioactive substances properly belongs. From him should come suggestions of new materials to be tried; of new methods to be employed in delivering the dosage necessary to be effective. The neurological surgeon must microscopically verify the tumor, so that there is no question of the type of tissue under study; he must devise techniques to continue Cushing's principles of the meticulous handling of nerve tissue. Both must join to study methods of measuring the biological responses of patients to malignant cells.

The experiences of the past in this type of cooperation between Roentgenology and Neurological Surgery point the way to the encouragement of a hopeful, if not an optimistic, attitude for success in the future.

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ROENTGENOGRAPHIC SIGNS OF TUMORS OF THE BRAIN*

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HISTORICAL BACKGROUND

RÖNTGEN'S discovery in 1895 of the x-ray which now bears his name resulted in an important adjunct to diagnosis in various fields of medicine. Among the branches of medicine to be benefited by the roentgen ray were neurology and neurosurgery.

One of the earliest uses of the roentgen ray in diagnosis was for the demonstration of metallic foreign bodies within the body and cranium.

Within two years of Röntgen's announcement of his discovery the first recorded evidence of the demonstration of a brain tumor was made by Obici and Ballici.[64] They made a roentgenogram of a brain tumor within the skull of a postmortem specimen. A year or two later Oppenheim[65] reported that he was able experimentally to determine that a tumor placed within the cranium in the brain tissue of a cadaver made a distinct shadow. His attempts to use the roentgen ray for diagnostic purposes to demonstrate tumors in the brain of the living patient, however, were a failure at that time.

In April, 1898, Church[16] of Chicago, with the assistance of Mr. W. H. Fuchs, first demonstrated in a roentgenogram the brain tumor in the living subject. The patient was a fifteen-year old boy who had developed signs and symptoms typical of a cerebellar tumor of two years' duration. Church was probably the first to show the value of the roentgen ray as a diagnostic procedure in the study of brain lesions.

Church in his roentgenogram showed an indistinctly lobulated mass in the right posterior fossa which he interpreted as being due to a tissue of a different character than the rest of the brain tissue, thus, probably a tumor. He presumed that the difference in tissue density was due to the high vascularity of the tumor. The condition was considered inoperable. Six months after the roentgenogram was taken, the boy developed a sudden severe headache and died. At necropsy the tumor was found to be a very vascular glioma and the seat of a number of old hemorrhages and a recent one. There was marked thinning of the bones of the cranial vault. No mention was made of the presence of any calcification in the tumor. However, Church said that calcareous masses would certainly cast a visible shadow, and that it might be possible to demonstrate tuberculomas, fibromatous tumors, and thickly encapsulated abscesses.

The second record of a brain tumor to be localized by means of the roentgen ray was made by Mills and Pfahler[57] at the Philadelphia General Hospital in 1901. This was a large subcortical tumor in the parietal region which, at autopsy, was called a fibrosarcoma.

Pfahler made a number of experiments on cadavers. He placed a preserved brain tumor in a cavity in the fresh brain in the skull and showed the shadow of the tumor on the roentgenogram. He repeated this experiment several times using both fresh and formalin hardened brain and in each case was able to show the tumor.

* Thesis submitted by Dr. Gilbertson to the Faculty of the Graduate School of the University of Minnesota in partial fulfillment of the requirements for the degree of Master of Science in Radiology.

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In 1901 Oppenheim noted the destruction of the posterior clinoid processes of the sella turcica and made a diagnosis of a pituitary tumor which was subsequently proved to be correct.

Some months later Mills and Pfahler[58] again demonstrated a brain tumor in the living subject by means of the roentgen ray. Reports of the use of the roentgen ray in the diagnosis of brain tumors gradually appeared. The literature accumulated slowly at first. Many of the early reports were made from the European countries.

Schüller[79–81] made several observations which were important in the diagnosis of brain tumors. He reported a series of 250 cases, in which a positive diagnosis was made in 150 instances. Fifty-four of these showed some involvement of the pituitary fossa.

In this country Cushing[21] noted the value of roentgenography in the diagnosis of brain tumor, especially in regard to disorders of the pituitary gland.

Early roentgenologic diagnosis of brain lesions was relatively unsatisfactory. During the work of the early investigators such as Church and Pfahler, exposures of between three and four minutes were required in order that the shadow cast by the tumor could be seen. Progress was made in 1916 when the Potter-Bucky diaphragm was developed, and again in 1918, when modern duplitized film came into being. These factors reduced the exposure time and increased the detail on the roentgenogram. Another contribution to localization of brain lesions was made in 1918 when Dandy[22] and Baetjer developed ventriculography and encephalography. By means of air studies of the ventricular system, tumors which were otherwise not discernible on the roentgenogram could be localized.

MATERIAL

This treatise is based on a survey of the proved cases of intracranial neoplasms that have been seen at the Mayo Clinic during the five year period between January, 1940, and January, 1945. The study was made in order to determine the value of roentgenologic examination in the localization of lesions in the brain. A secondary purpose was to compare the material compiled at the Mayo Clinic to material compiled in similar surveys at other large clinics and hospitals.

In order for a case to be included in the series the following conditions were met: (1) There were available roentgenograms of the head including stereoscopic lateral views, a posteroanterior view, and a view in the Towne position. In a number of cases additional views were available if further roentgenographic study was deemed necessary; (2) there was histologic proof of the nature of the lesion; (3) the site of the lesion was determined either at operation or at necropsy.

A total of 661 cases met these criteria. The preoperative roentgenograms were either not available or were considered technically unsatisfactory for diagnosis in a small percentage of operative or necropsy cases so that these are not included among the cases taken for study. Excluded also from this group of lesions were neurofibromas of the eighth cranial nerve, the so-called acoustic neuromas.

The additional knowledge that can be gained from encephalography and ventriculography is fully recognized. However, these findings are not included within the scope of this survey since this is an effort to determine the value of the routine skull examination in the diagnosis of brain tumor.

Each set of roentgenograms was reviewed and the positive and negative findings were noted on tabulation cards, which could later be mechanically sorted. Other data on each card included the name, registration number, sex, age, proved site of the tumor, and histopathology of the tumor tissue.

Pathologically, the tumors were arranged according to a modification of Bailey's classification of brain tumors. The pathologic diagnosis which was accepted was that

TABLE I

ROENTGEN SIGNS IN 661 BRAIN TUMORS

	Total	Positive	Negative	Supratentorial	Infratentorial	Calcification	Bone Changes	Pineal Shift	Sellar Erosion	Suture Separation	Digital Markings	Increased Vascularity
Total tumors	661	426	235	539	122	101	99	83	306	40	83	35
Glioma	326	173	153	238	88	48	20	30	117	36	65	13
Glioblastoma multiforme	136	50	86	124	12	6	7	16	35	2	8	7
Astrocytoma	98	60	38	54	44	13	5	12	43	21	30	3
Oligodendroglioma	35	27	8	34	1	19	6	—	13	—	4	1
Ependymoma	26	16	10	11	15	7	2	—	11	4	8	2
Medulloblastoma	16	10	6	1	—	—	—	—	5	7	10	—
Pinealoma	5	4	1	5	—	1	—	—	4	—	1	—
Ganglioneuroma	2	2	—	2	—	—	—	—	2	—	2	—
Gliomas unclassified	8	4	4	7	1	2	—	2	4	1	2	—
Meningioma	154	109	45	139	15	29	64	37	56	—	3	19
Chromphobe adenoma	99	95	4	99	—	4	—	7	95	—	2	—
Craniopharyngioma	25	19	6	25	—	17	—	—	19	2	8	—
Hemangioblastoma	18	8	10	6	12	—	5	4	6	—	4	—
Metastatic carcinoma	9	4	5	8	1	—	1	3	2	—	—	—
Sarcoma and fibrosarcoma	13	6	7	11	2	—	4	1	3	—	1	1
Epidermoid	9	8	1	7	2	3	3	—	4	—	—	—
Miscellaneous	8	4	4	6	2	—	2	1	4	2	—	1

made by Dr. J. W. Kernohan,* neuropathologist at the Mayo Clinic.

ROENTGEN SIGNS OF BRAIN TUMOR WITH REVIEW OF LITERATURE

In some patients with a brain lesion the neurologic signs and symptoms are of such a nature that a roentgenologic examination is not necessary for localization. In these, roentgenograms are taken for corroborating evidence. In another group of patients the roentgenogram provides leads as to the anatomic site and extent of the tumor, and it may help to determine the method of surgical approach.

In general, one of three findings will be obtained from the roentgenogram: (1) definite localizing signs; (2) signs of increased intracranial pressure without definite localizing signs; or (3) a negative examination:

A. Localizing signs:
   1. Calcification within the lesion.
   2. Pineal and/or choroid shift.
   3. Hyperostosis and osteomatous formation.
   4. Erosion or destruction of bone.
   5. Erosion of sella turcica (in intrasellar tumor).
   6. Increased vascularity.

B. General signs of increased intracranial pressure:
   1. Erosion of sella turcica
   2. Separation of sutures.
   3. Hydrocephalus.
   4. Convolutional atrophy
   5. Increased vascularity.

Calcification. The most obvious localizing sign of a brain tumor is the recognition of calcium within the lesion. One of the largest early series of cases in which the roentgenogram was used in localization was reported in 1916 by Heuer and Dandy.[37] They presented 100 cases of brain tumor,

* Dr. Kernohan's classification of brain tumors has been revised since this paper was written.

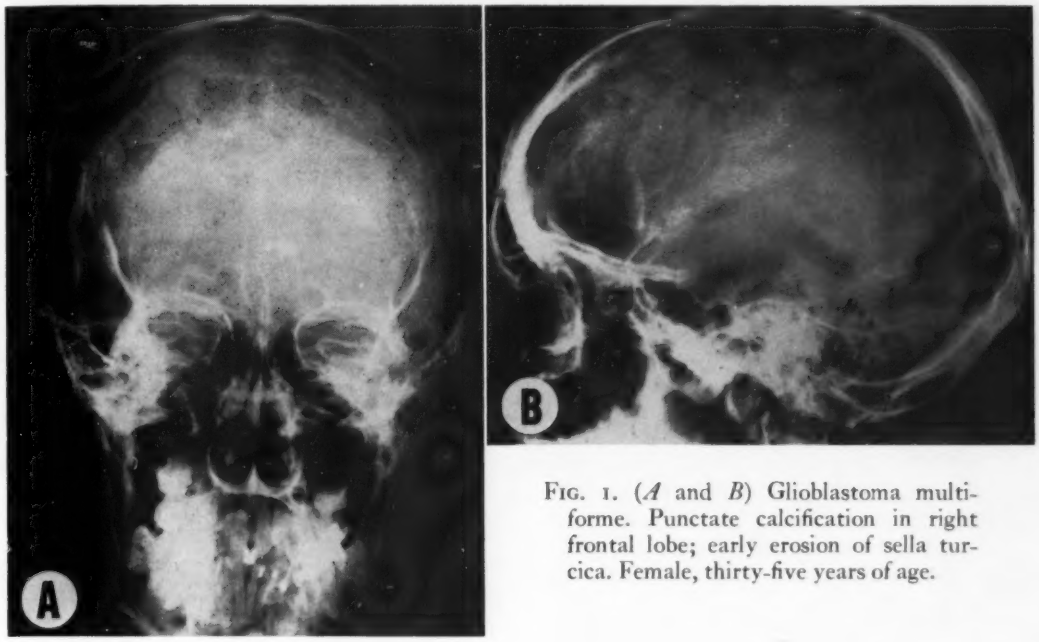

FIG. 1. (*A* and *B*) Glioblastoma multiforme. Punctate calcification in right frontal lobe; early erosion of sella turcica. Female, thirty-five years of age.

68 of which were subsequently proved by surgery or necropsy. Six per cent of their series showed calcification. Histologically these consisted of one each of glioma, osteosarcoma, Rathke's pouch tumor, hypophysial tumor, sarcoma of the optic chiasm, and aneurysm of the internal carotid artery. The roentgenographic examination was considered to be of value in 45 per cent of cases.

Up to 1923, Newell[63] found only 38 cases in the literature in which there was evidence of calcification in the brain. Sosman's[83] survey of 1,146 cases from Cushing's Clinic showed that calcification varied with the type of tumor. Gliomas made up 43 per cent of the tumors, but of these only 10 to 12 per cent were visible as a result of their calcium content. Rathke's pouch tumors made up 5 per cent of the total and were calcified in 70 per cent of cases. Meningiomas were localized in 50 per cent of cases, but calcification was not mentioned.

According to Schwartz,[76] 13 per cent of gliomas were found to be calcified. Kornblum[45] found calcification in 6.5 per cent of brain tumors. Of 131 verified gliomas studied by Masson,[54] 13 per cent were found to show calcification. Courville and Adelstein[17] found calcification occurring most often in craniopharyngiomas and second most commonly in gliomas. Sachs[73] reports tumor shadows visible due to calcification in 8 to 10 per cent. A study by Camp[14] at the Mayo Clinic prior to 1930 showed calcification in 7.6 per cent of 81 verified cases. Five per cent of these were in gliomas. Strom found calcification in 6 per cent. In 1923 Crouse[18] found calcification in 3 per cent. Wood[91] found microscopic evidence of calcification in 40 per cent of 55 brain tumors.

The type of calcification in a tumor is not considered by most observers to be diagnostic of the type of tumor. Masson[54] does not believe that the calcification in gliomas can be differentiated from the calcification in an old abscess or in cerebral degeneration following a vascular accident. The calcification in gliomas has been described by various observers such as Camp, Sosman, and Schwartz, as coarse, irregular, streaked, mottled, or linear. Calcification in meningiomas is less evident because of the frequent association with osteomatous thickening of the skull. The calcium, according to Camp, is apt to be in punctate, discrete

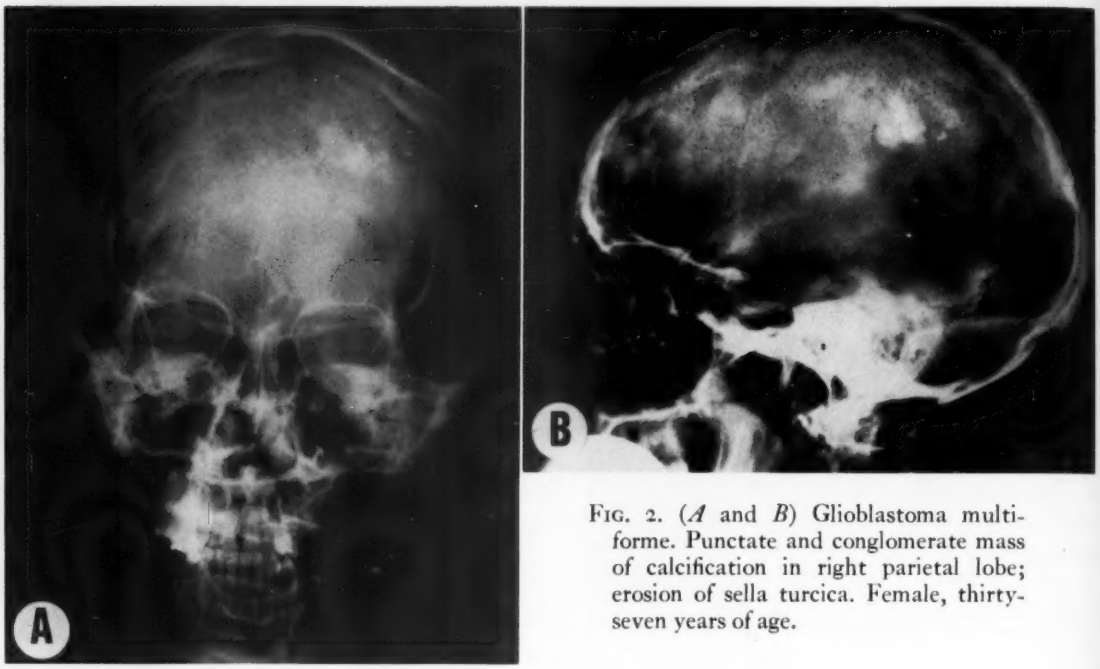

FIG. 2. (*A* and *B*) Glioblastoma multiforme. Punctate and conglomerate mass of calcification in right parietal lobe; erosion of sella turcica. Female, thirty-seven years of age.

masses which may become conglomerated into a large dense mass.

The site of the calcification may be an aid in more accurate diagnosis. The high incidence of calcification in suprasellar cysts (Rathke's pouch tumors) has been frequently mentioned. McKenzie and Sosman[52] found that 70 per cent calcified and that the calcification might be either within, or in the region of, the sella turcica. The highest incidence of Rathke's pouch tumors is in patients under thirty years of age. Lime salt deposits in meningiomas are found in the sites of highest incidence of meningiomas. These are along the sagittal sinus and at the base of the skull in the anterior fossa. The calcification, says Camp, is generally in the capsule of the tumor and may simulate calcification of the falx. Calcification in the bones of the skull may be due to angiomatous growths or to epidermoids. Epidermoids, according to Brock and Klenke,[9] and Camp have a central area of rarefaction with a dense, well circumscribed area of increased density at the periphery which simulates calcification.

Gillies[35] and Schwartz[76] both stated that calcification in the cerebellum in a child, especially if it is near the midline, is most apt to be in an ependymoma. Schwartz stated that medulloblastomas in children calcify infrequently.

Calcification in a glioma was found by Masson[54] and Courville and Adelstein[17] to be an indication of its relative rather than absolute benignity. Masson explains calcification in fast growing tumors, such as spongioblastomas, as resulting from deposition of lime salts in groups of well differentiated cells which are sometimes found in some parts of the tumor.

Pineal Shift. The pineal body was probably first described anatomically by Oribasius and Galen. Calcification in it was observed by Galen who thought it was of pathologic significance. As early as 1785 Sommering considered the calcification to be of no importance. Although no pathologic significance has yet been ascribed to calcification in the pineal gland, when it is calcified it may be of help in the localization of space-occupying lesions within the cranium.

Calcification in the pineal gland was first shown roentgenographically by Schüller[81] in 1906. In 1912 he outlined the normal position of the pineal gland in the horizontal and vertical planes, and suggested

the diagnostic value of its displacement in a case of brain tumor. Naffziger[62] in 1925 found the pineal gland calcified in 45 per cent of 215 patients. Calcification occurred in 58 per cent (96 cases) of patients over twenty years of age and in only 15 per cent (45 cases) of patients under twenty years of age.

In 1927 Vastine and Kinney[89] reported the determination of normal variation in the position of the pineal gland. They measured the distance from the gland to the inner table of the frontal and occipital bones, and to the inner table of the vault and base of the skull. These measurements were charted and it was found that a variation of 1 cm. in the anteroposterior position in the lateral view could be normal. Their series consisted of 268 cases of which 163 (47 per cent) showed a calcified pineal gland. Fifty-nine per cent of these patients were over twenty years of age.

Frontal lobe tumors, whether gliomas or meningiomas, caused a posterior displacement of the pineal gland in 71 per cent of cases while parietal lobe tumors caused a downward displacement in 47 per cent of cases. Sixty-two per cent of these tumors were meningiomas and 38 per cent were gliomas. Forty per cent of temporal lobe tumors caused posterior pineal displacement. Occipital tumors caused an anterior shift in 44 per cent of cases, regardless of tumor type. Thirty-three per cent of subtentorial tumors caused an upward displacement; while 22 per cent of acoustic neuromas and 10 per cent of adenomas caused a similar change. In hydrocephalus alone there was upward displacement in 13 per cent of cases.

Dyke[26,27] found a calcified pineal gland in 51 per cent of 2,724 roentgenograms of the skull which he examined. Fifty-nine per cent of these were in patients over twenty. Only 5.1 per cent were in patients under ten years of age. Thirty-nine per cent of brain tumors in his series caused pineal displacement; 53 per cent of the gliomas and 43 per cent of the meningiomas.

Fray[32] made determinations of the position of the pineal gland using the proportional method of Vastine and Kinney, then developed a modification which he called the cranio-angle method. He found that frontal lobe tumors most frequently caused a pineal shift. The shift was generally backward, less commonly downward and back-

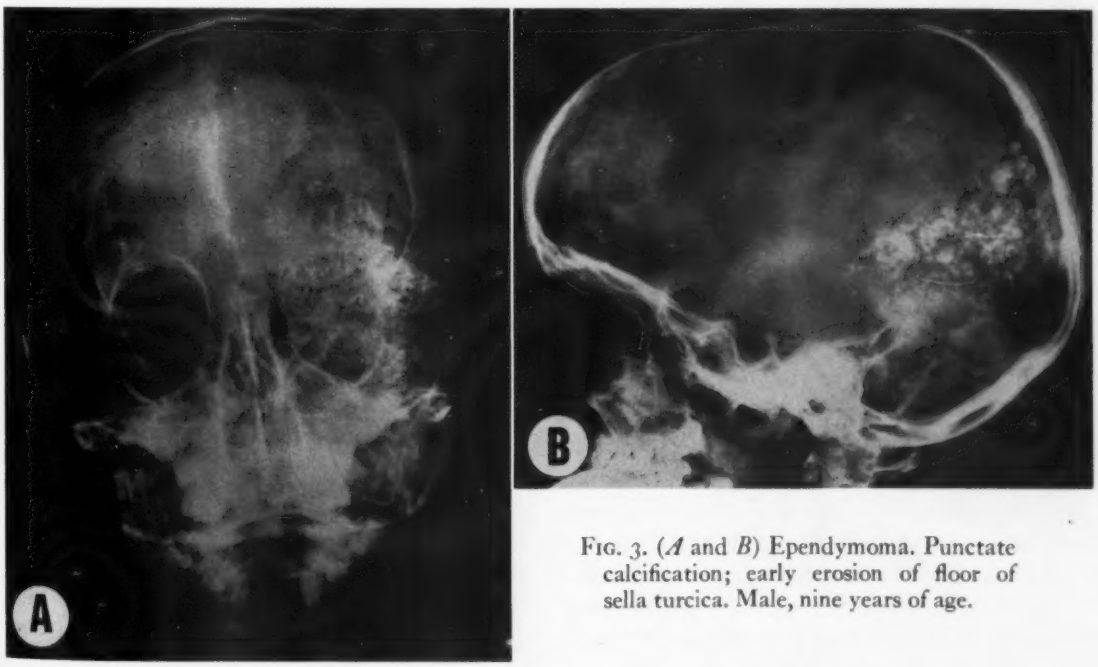

Fig. 3. (*A* and *B*) Ependymoma. Punctate calcification; early erosion of floor of sella turcica. Male, nine years of age.

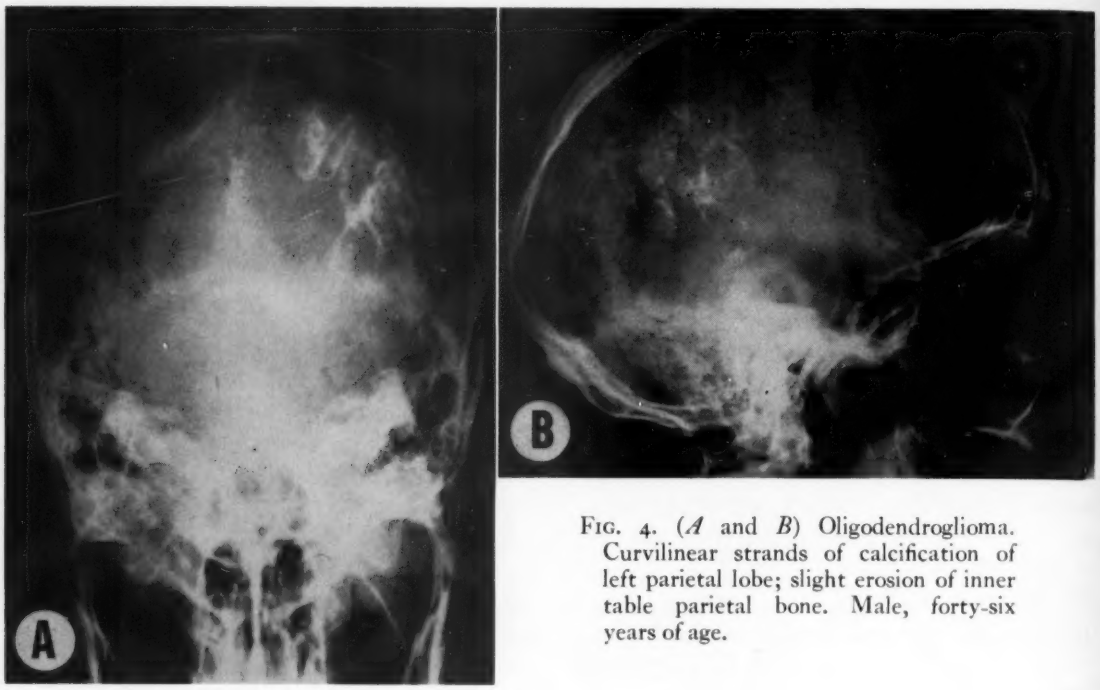

FIG. 4. (*A* and *B*) Oligodendroglioma. Curvilinear strands of calcification of left parietal lobe; slight erosion of inner table parietal bone. Male, forty-six years of age.

ward and very seldom to the side. Parietal or temporal lobe tumors produced a lateral shift. Cerebellar tumors seldom affected the pineal gland. One reason for this, Fray pointed out, is that cerebellar tumors are more numerous in children, the age group in which the pineal gland is infrequently seen. Pituitary tumors occasionally produced a slight shift.

Camp[14] found calcified pineal glands in over 60 per cent of patients over twenty years of age. He called attention to the downward displacement in certain cases of hydrocephalus, and remarked that it should not be misinterpreted as being due necessarily to a parietal or temporal lobe tumor.

Boenning found that 70 per cent of 3,300 cases showed a calcified pineal gland. The incidence of calcification in the pineal gland has also been reported by other observers, as follows: Browner, 30 per cent of 70 cases; Erdelje, 50 per cent of cases; Low-Beer, 40 per cent of cases; Gravstad, 80 per cent of 130 cases; Dibbern, 45 per cent of 290 cases; Lilja, 37 per cent of 800 cases. Lilja[48] found no visible pineal glands in children under ten years of age. Among 217 cases of brain tumor which he studied, he showed a lateral shift in the posteroanterior view in 53 per cent of 34 cases of supratentorial tumor and no instances of shift in 17 cases of infratentorial tumor. In the lateral view he found a pineal shift in 50 per cent of 139 cases of supratentorial and 14 per cent of 78 cases of infratentorial tumor. The apparent discrepancy in number of cases is due to the fact that the pineal gland is visualized more often in the lateral view than in the posteroanterior view because of the difference in the diameters of the skull.

Schüller[81] in 1906 reported the roentgenographic demonstration of calcification in the choroid plexus. Dyke and Davidoff[28] found that calcification in the choroid plexus was seen in 5.1 per cent of 2,724 roentgenograms of the skull. Childe[15] found calcification in 11.2 per cent of 1,000 cases. Schwartz[76] demonstrated calcification in 13 per cent of his series. The incidence of calcification of the choroid plexus increases if the patients are over twenty years of age. Beals[6] found calcification in 26 per cent of such a group. Dyke and Davidoff found calcification of the choroid plexus in 9.4 per cent of patients over forty years of

age. Wood[91] reported calcification of the choroid plexus in a child two and one-half years old and also in one three years old.

Although the choroid plexus lies along the roof of the third ventricle and in the body and inferior horns of the lateral ventricles, it is most abundant at the junction of the body of the lateral ventricle with the inferior horn. This bend in the plexus is called the glomus, and it is in this region that calcification most frequently occurs. The glomus is located approximately 2.5 cm. lateral to the midline in the anteroposterior projection, and 1 cm. posterior and 0.5 cm. above the pineal gland in the lateral view. Calcification is very rarely noted in the midline but has been reported in the third ventricle. None has ever been reported as visualized by roentgenologic methods in the fourth ventricle.

Calcification of the choroid plexus is almost always bilateral and symmetrical. Childe found the calcification to be unilateral in 1.9 per cent of cases. Asymmetrical calcification should not preclude a tumor unless the asymmetry is marked. In most cases of Wood's series in which the roentgenogram showed a displacement of one choroid glomus, other evidence of an expanding intracranial lesion was also present.

The appearance of the choroid has been described variously; Camp compared the punctate shadows to clusters of tiny glass beads. Dyke and Davidoff noted the resemblance to popped kernels of corn. Others have described the calcification as linear or crescentic. The crescentic shape is likely to be assumed if the calcification extends into the temporal horns.

Displacement of the choroid plexus by space-occupying lesions has been described by Lowman and von Storch,[50] Fray,[33] Pancoast,[68] Childe,[15] Wood,[91] Jacobsson,[39] Dyke and Davidoff,[28] Pendergrass and Schaeffer,[69] and Newell.[63] Displacement is most likely to occur as a result of tumors which are located posterior to the glomus or as a result of those in the temporal lobe. The direction of displacement is forward, upward, or toward the midline.

Hyperostosis. Due to their effect on adjacent bone a larger number of meningiomas than gliomas can be localized by means of the roentgenographic examination.

Virchow[90] recorded thickening of the skull over endotheliomas of dura in 1864. At that time the thickened skull was considered either to be due to stimulation of the bone by the tumor or to be a separate entity. Spiller[85] pointed out in 1907 that localized hyperostosis of bone in the skull was likely to be associated with a tumor of the underlying meninges. Barling and Leith[5] in 1906 found that cells in the osteomatous thickening overlying meningiomas were of the same nature as those in the tumor, and they considered the tumor to be primary in the meninges with secondary invasion of the bone.

Cushing found osteomatous thickening in 25 per cent of 80 cases of meningioma. Tumors of the frontal and temporal regions, especially those originating near the falx, produced hyperostosis most often. Cushing described two types of meningioma: (1) A spherical, irregularly lobulated form of tumor, imbedded in the brain with a variable amount of attachment to the dura, and (2) the "endothelioma en plaque," with a broad dural attachment, slight indentation of the brain surface, and a greater capacity to produce hyperostosis.

Sosman identified roentgenologically 50 per cent of the meningiomas in his series of 1,145 brain tumors from Cushing's Clinic. Meningiomas made up 12 per cent of the verified brain tumors.

The new bone formation caused by a meningioma may consist of an exostosis or osteoma of either or both of the tables of the skull, of thickening and increased density of the adjacent calvarium, or of spicules of bone which lie perpendicularly to the tables of the skull.

Kornblum[45] found local hyperostosis in 1.8 per cent of all intracranial tumors in a series of 446 cases. This hyperostosis was more frequently found in the anterior portion of the calvarium or at the base of the skull.

Erosion of Bone. Destruction or erosion

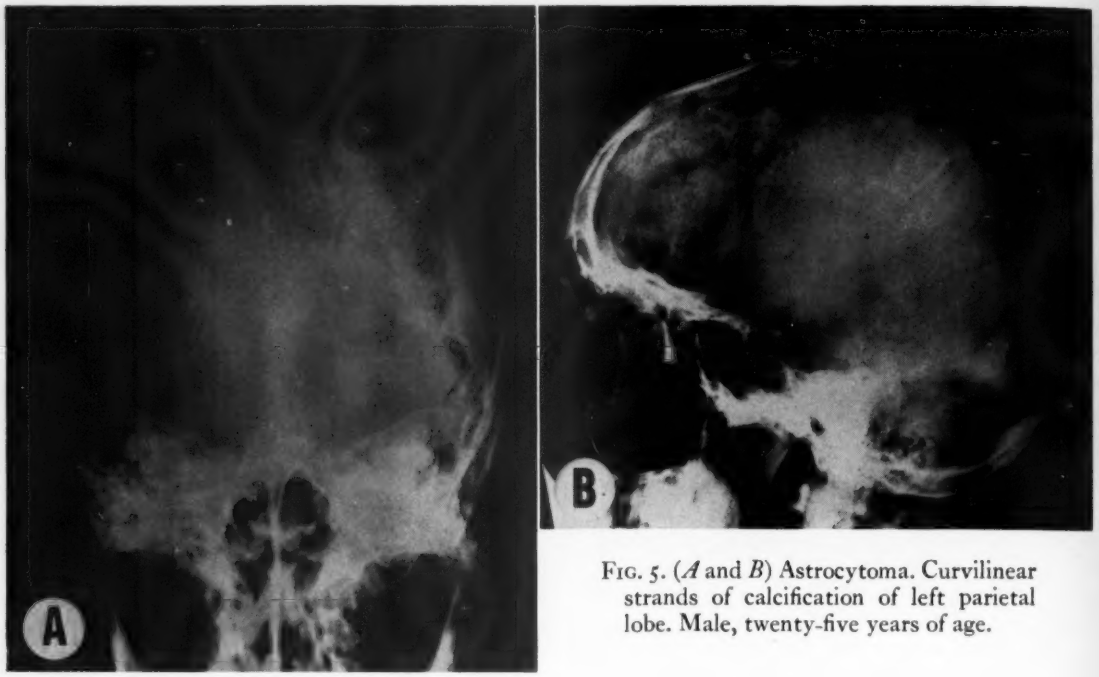

Fig. 5. (*A* and *B*) Astrocytoma. Curvilinear strands of calcification of left parietal lobe. Male, twenty-five years of age.

of bone may be a local effect produced by pressure on, or invasion of, the bone or tumor, or it may be due to a generalized increase of the intracranial pressure.

Local bone erosion was present in 2.9 per cent of Kornblum's[45] series of brain tumors.

Not uncommonly meningiomas cause both erosion and increased bone formation. Five types of bone response are listed by Boldrey,[8] quoting Cushing and Eisenhardt: (1) Invasion and destruction of overlying skull; (2) worm-eaten appearing skull due to invasion of haversian canals of skull and galea: (3) proliferative reaction in the tables of the skull with spicule formation and fusiform thickening, but with preservation of the original tables; (4) homogeneous bony projection of the inner table, especially at the base of the skull in the anterior fossa; (5) no bone change.

Erosion of the petrous pyramid is found in some neurofibromas of the acoustic nerve. Sosman[82] was able to identify 5 per cent of tumors of this type. Acoustic neuromas constituted 9 per cent of the brain tumors in the series of Schwartz[78] and that of Sosman. Pancoast[67] called attention to normal depressions in the petrous ridge on either side, but more frequently on the right side because of the fact that the right lateral sinus is larger. He was able to identify 2 per cent of acoustic neuromas because of the erosion of the petrous pyramids.

In the diagnosis of tumors of the pituitary gland the roentgen examination attains its highest degree of proficiency in regard to lesions of the brain. Sosman was able to recognize 90 per cent of adenomas of the pituitary gland due to expansion of the sella turcica. Adenomas of the pituitary gland made up 19 per cent of the brain tumors in his series. Another group of lesions of the pituitary fossa, which amounted to 5 per cent of the brain tumors in his series, were the Rathke's pouch tumors. Seventy per cent of these could be recognized by means of the roentgenogram; 70 per cent showed calcification and 60 per cent produced an expansion of the sella turcica. Pancoast identified 89 per cent of the pituitary tumors in his series.

Pancoast quoted Kornblum's classification of lesions affecting the sella turcica: (1) Intrasellar, producing atrophy of the anterior aspect of dorsum and thinning of

the floor; (2) metasellar, due to third ventricle obstruction, producing unilateral erosion of the sella turcica either from direct pressure by the tumor or from indirect pressure through the internal carotid artery; and (3) suprasellar, such as vestigial rests from craniopharyngioma, producing calcification in the tumor with somewhat less deformity of the sella.

General Signs of Increased Intracranial Pressure. In a large number of cases the only roentgenographic evidence of a brain lesion is pressure erosion of the sella turcica. Camp stated that any tumor causing increased intracranial pressure because of its size or because of obstruction of the ventricular system may produce erosion of the sella. These extrasellar tumors result in a wide flat sella. The posterior clinoids are eroded from above and become short and pointed. Erosion of the floor occurs early, and erosion of the anterior clinoids occurs later in increased pressure. The amount of destruction in the anatomic specimen was frequently greater than seemed evident from the roentgenogram.

Separation of the sutures was found in 4.6 per cent of Kornblum's cases. It has been noted in only the younger age group by most observers.

Increased vascularity has been seen most often associated with meningiomas and is usually accompanied by erosion of bone (Gillies,[35] Sosman and Putnam,[84] Heuer and Dandy[37]). The vascular changes include widened diploe and dilatation of the groove of the meningeal artery.

So-called convolutional atrophy and increased convolutional markings have been considered to be a result of increased intracranial pressure.

Kornblum and Kennedy[46] studied 494 normal skulls to determine the types of sphenoidal fissures or superior orbital fissures. They believed that the sphenoidal fissure could be altered by a local or distant tumor or aneurysm. From a study of 466 cases of brain tumor they showed that a deformity of the sphenoidal fissure occurred in 27 per cent. They stressed the importance of a roentgenogram, and believed that the findings should be correlated with the sellar changes.

General Incidence of Roentgen Signs of Brain Tumor in Total Group

This series consists of 661 cases of proved brain tumors. Of this number 326 or 49 per cent were of the glioma type. There were 154 meningiomas (23 per cent). Pituitary adenomas accounted for 99 cases or 15 per cent. Other tumors consisted of 25 craniopharyngiomas (3.7 per cent), 18 hemangioblastomas (2.7 per cent), and 22 intracranial carcinomas and sarcomas including fibrosarcomas (3.3 per cent). The remainder was composed of a miscellaneous group of 17 tumors including epidermoids, chordomas, porencephalic cysts, and tuberculomas.

Of the total number of cases examined, 426 or 64 per cent showed positive signs of an intracranial lesion on the roentgenogram. The highest degree of positive findings was in the pituitary adenoma group where 95 of the 99 cases showed some evidence of erosion of the sella turcica. One hundred nine or 71 per cent of the meningiomas showed some roentgenographic evidence of their presence. In the glioma group 53 per cent gave some indication of their presence.

Calcification in the tumor and localized bony changes in the skull constitute the main roentgenographic localizing signs of an intracranial tumor. Pineal shift is a less definite localizing sign, but, if present, may give a general impression as to the tumor site.

Calcification was found in 101 or 15 per cent of the total group. Bony changes were also present in 15 per cent. Bony proliferation in the form of osteomas or hyperostosis comprised the largest part of this group. Erosion of the skull as the result of brain lesions was found in 7 per cent.

The pineal gland was calcified to the extent that it could be seen roentgenographically in 284 or 43 per cent of all the cases. A displacement of the pineal gland was noted in 12 per cent of the cases examined, but

FIG. 6. Craniopharyngioma. Punctate calcification in suprasellar region with erosion of dorsum sellae. Male, eighteen years of age.

displacement occurred in 29 per cent of those cases in which the pineal gland was visualized. A lateral shift was more common than a vertical shift.

Calcification in the choroid plexus was found in 41 of the cases. This was an incidence of 6 per cent. Choroid plexus calcification usually occurs at the glomus which is at the junction of the body and inferior horn of the lateral ventricle and is seen as a cluster of calcified material varying in size from 0.5 to 1.5 cm. In this series, the calcification was bilateral in the majority of cases. In cases of unilateral calcification it must not be mistaken for a displaced pineal gland. Normally, the pineal gland lies inferior and anterior to the glomus of the choroid plexus. Shift of the pineal gland to such an extent that it occupied the position of the normal location of the choroid glomus was rarely seen.

Shift of the choroid plexus was not found to be of much value as a localizing sign. A shift was present in only 4 of the cases, and in each of these, other signs, including a shifted pineal gland, were also seen.

Erosion of the sella turcica was present in 306 cases (45 per cent). This figure includes the intrasellar pituitary chromophobe adenomas and the craniopharyngiomas, in both of which the appearance is generally rather characteristic. Exclusive of these two groups, erosion of the sella turcica due to increased intracranial pressure was present in 192 cases or 28 per cent.

Suture separation was of little value as a localizing sign, but it did indicate increased intracranial pressure. It was found almost entirely in the younger age group. Seventy-five per cent of the patients showing suture separation were in the first decade of life. The finding was present in 6 per cent of the total number of cases. The large majority was in the glioma group which included tumors more common in children. No suture separation was found in the meningioma group.

Erosion of the petrous pyramid was found very infrequently, in only about 1 per cent of cases. This low incidence was largely due to the fact that acoustic neuromas, which typically cause erosion of the petrous pyramids, were excluded from this survey. Deformity or decalcification of the sphenoidal fissure due to local or general increased pressure was likewise seen very infrequently, except in the cases of meningiomas of the sphenoidal ridge.

Digital markings are sometimes thought to be due to increased intracranial pressure. In this series, 83 cases or 13 per cent were considered to have increased markings, but 62 of these were in patients under twenty years of age. Digital markings, however, are commonly seen in the normal child's skull, hence the value of this sign is to be questioned. It is likely that digital markings in skulls, especially up to the age of twenty-five, should not be considered abnormal, unless there are accompanying roentgenologic or neurologic signs.

Increased vascularity in the skull, either generalized or localized, was seen in less than 5 per cent of cases. Most of this was in association with meningiomas. Vascularity of the skull varies markedly in normal individuals and the interpretation of increased vascular markings must be made with care. Unless other evidence of a brain lesion is present, it is generally safer not to place much reliance on the sign.

The majority of gliomas were located supratentorially. Exceptions to this rule were ependymomas and medulloblastomas.

Of the latter, 15 were infratentorial and only 1 was situated above the tentorium. Fifteen ependymomas were also infratentorial, but 11 were in the cerebrum. Only 12 glioblastoma multiformes were found in an infratentorial position, while 124 were in a supratentorial location. Of the 35 oligodendrogliomas, only 1 was beneath the tentorium. Astrocytomas were the most equally divided, 54 supratentorial, 44 infratentorial.

INCIDENCE OF SIGNS IN RELATION TO SPECIFIC TUMOR TYPE

Gliomas

Calcification. Calcification in the various types of tumors tended to be fairly characteristic, and in a number of cases the histologic type could be suspected. Thirty-five oligodendrogliomas were encountered. This constituted 11 per cent of the gliomas. Calcification was found in over half of these cases (54 per cent). The calcification was most frequently laid down in coarse, irregular strands or streaks, some of which tended to take a curvilinear shape. This was true in 14 of the 19 cases. At least some of this arrangement is probably due to a perivascular deposition of calcium in the tumor. The other 5 oligodendrogliomas showed calcification in the form of irregular masses. At times the calcification involved a large area, and more of the tumor appeared to be calcified than was the case in some of the other types of tumor.

The lime deposits in astrocytomas were similar to those in oligodendrogliomas, and it is not likely that a differential diagnosis between the two could be made from the roentgenogram. The pattern consisted of the same type of broad or narrow trabeculae or curvilinear plaques. Ninety-eight (30 per cent) of the gliomas studied were astrocytomas. Calcification was seen in 13 of these, an incidence of 13 per cent. Eight of the 13 exhibited the typical irregular strands which sometimes took the curvilinear form. In 3 of the remaining the calcium was deposited in small irregular plaques. These 3 were all in patients over forty years of age. In only 2 of the calcified tumors was the deposit punctate in character and 1 of these was considered by the pathologist to show elements of both an astrocytoma and glioblastoma. Only 3 of the patients with astrocytomas in which calcification was seen were over forty years of age; the average age was two or three dec-

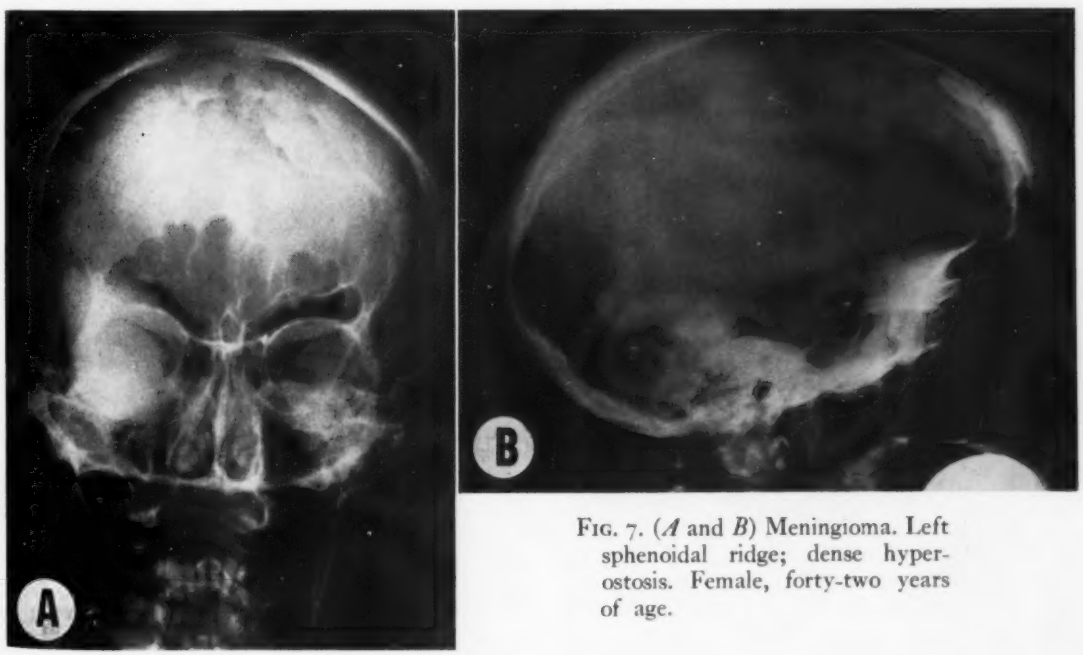

Fig. 7. (*A* and *B*) Meningioma. Left sphenoidal ridge; dense hyperostosis. Female, forty-two years of age.

ades younger than that encountered in glioblastoma.

The most common type of glioma observed was the glioblastoma multiforme also called spongioblastoma multiforme. Of the 326 gliomas, 136 or 43 per cent were glioblastomas. These are among the most rapidly growing brain tumors. This probably accounts for the small number which showed any calcification. Only 6 were calcified, an incidence of less than 5 per cent. The calcification was deposited in coarse or fine flecks or punctate areas in 4 of the 6 cases. In one of the remaining cases the flecks were in association with a small osteoma of the inner table, and in the other case a few irregular strands of calcium could be seen. The tendency, thus, was for the calcium to be laid down in punctate areas. The tumor almost always occupied a greater volume than would be indicated by the calcium deposit. Of the 136 glioblastomas 106 (77 per cent) were in patients over forty years of age. Ten of the tumors in the other 30 patients were located infratentorially. None of these was calcified.

Ependymomas made up 26 of the gliomas or 8 per cent. Of these, 7 or 27 per cent were calcified. Ependymomas also showed irregular punctate masses of calcification (5 of the 7 cases), but they occurred more frequently in the first two decades of life. Punctate calcification in a tumor in a child's skull is most apt to be found in an ependymoma.

Sixteen (5 per cent) medulloblastomas were seen. No calcification was evident in the roentgenogram in any of these tumors. This again is in keeping with the relatively rapid rate of growth of these tumors and the fact that they occur in younger individuals. The oldest patient in the group of medulloblastomas was twenty-five years old. All of the remainder were in patients less than eighteen years of age.

Only 2 ganglioneuromas were found. Neither of these was calcified. Five pinealomas were seen. One of these showed a small curvilinear shadow of calcification near the midline in the periphery of the tumor. Two of 8 additional gliomas which were not further classified as to type were calcified.

Pineal Displacement. Pineal displacement occurred more frequently in patients suffering from the faster growing gliomas. A shift was seen in 2 of the cases of unclassified gliomas. Sixteen cases of glioblastoma showed a shift. Displacement to either left or right in the posteroanterior view was more common than a vertical shift. Among the cases of astrocytoma, 12 showed a pineal shift. No displacement was noted in any cases of the other gliomas. Medulloblastomas are rapidly growing, but occurred most frequently in children where only a small percentage of the pineal glands were visible on the roentgenogram. In the total group of tumors, the pineal gland was seen in only 5 per cent of patients under twenty years and in less than 1 per cent of patients in the first decade of life.

Change in Bone. A visible effect on the bones of the skull as the result of gliomas was relatively infrequent.

Bone changes were more often of an erosive nature rather than purely destructive or proliferative. Two glioblastomas caused erosion of the inner table of the skull contiguous to the tumor. Five astrocytomas, 4 oligondendrogliomas and two ependymomas caused bone erosion. Proliferation of bone adjacent to the tumor was seen in 5 cases of glioblastoma and in 2 cases of oligodendroglioma.

Erosion of the sella turcica was the most common pathologic finding in the roentgenograms of patients with a glioma. Erosion occurred either directly, because of the size and position of the tumor, or secondarily, as the result of obstruction of the ventricular system. There did not seem to be much correlation between the site of the tumor and the amount or the site of erosion of the sella turcica unless the tumor was immediately adjacent to the sella turcica or caused early obstruction of the third ventricle. Erosion of the sella turcica, thus, was not a localizing sign, but did indicate the existence of intracranial pressure.

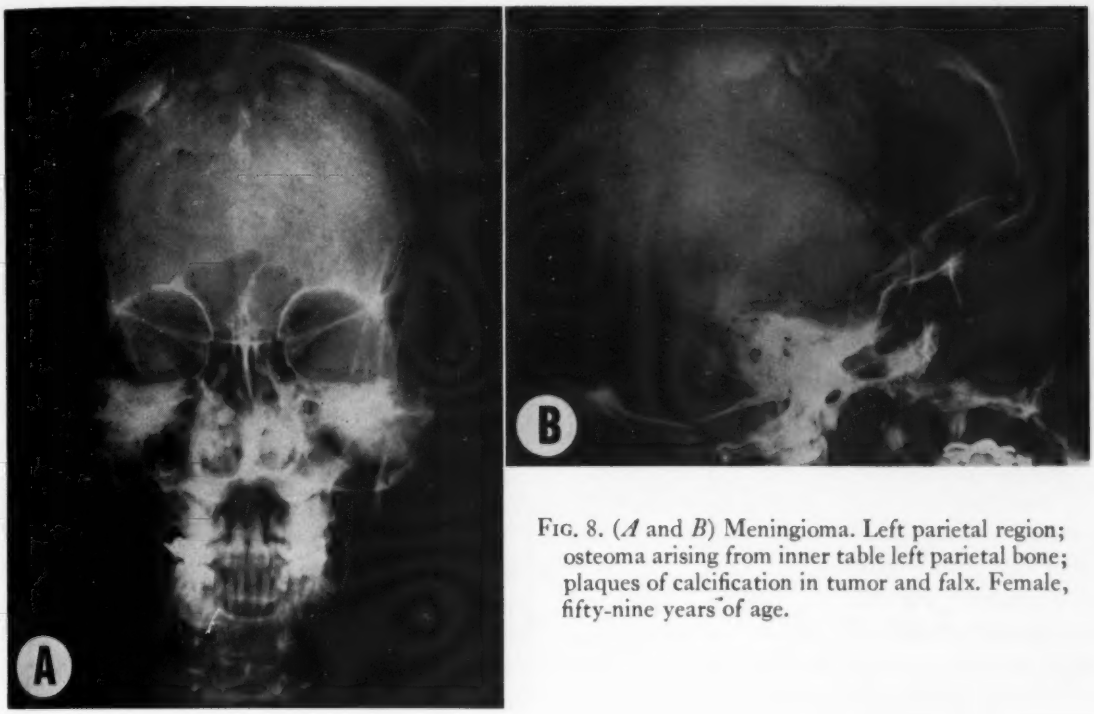

Fig. 8. (*A* and *B*) Meningioma. Left parietal region; osteoma arising from inner table left parietal bone; plaques of calcification in tumor and falx. Female, fifty-nine years of age.

In contradistinction to primary pituitary tumors where the posterior clinoids were the site of the earliest involvement, the floor of the sella turcica was sometimes involved first as the result of increased intracranial pressure. The earliest evidence of erosion of the sella turcica was a haziness of the floor. Later the posterior clinoids were eroded from above, the result being a flattened, widened sella turcica. The posterior clinoids became shorter and pointed as erosion progressed. Erosion of the floor was noted in 35 per cent of the cases of glioma and erosion of the dorsum was seen in 26 per cent. The anterior clinoids were usually involved late in cases of increased intracranial pressure, being involved in only 1 per cent of the cases of gliomatous tumors.

Twenty-five per cent of the cases of glioblastoma multiforme were manifested by erosion of the sella turcica. Astrocytomas caused the highest incidence of erosion of the sella turcica among the gliomas where the groups were considered large enough to tabulate an accurate percentage; the sella turcica was eroded in 44 per cent. Oligodendrogliomas caused erosion of the sella turcica in 37 per cent of the cases. Forty-two per cent of ependymomas caused sellar erosion and 31 per cent of the medulloblastomas. Only 5 cases of pinealoma were included in the group but 4 of these showed erosion of the sella turcica. Both of the ganglioneuromas caused similar erosion.

Suture Separation. Separation of the sutures is another sign of intracranial lesion, but it does not aid materially in localization. It was found in a total of 40 cases of the entire group, 36 being gliomas. One of the patients was in the decade from twenty to twenty-nine. Nine were in the decade from ten to nineteen, and all of the remainder, 30, were in the first decade.

As would be expected from their predominance as a tumor of childhood when compared to other tumors, medulloblastomas caused the highest incidence of suture separations, 44 per cent. Astrocytomas caused the second highest incidence, 22 per cent. Fifteen per cent of ependymomas, only 2 glioblastomas and 1 ganglioneuroma

caused separation. No pinealoma or oligodendroglioma caused such a change.

Digital Markings. Skulls of many normal children show some degree of digital markings. In this series 35 gliomas were considered to show prominent digital markings. Of these, 40 per cent of the patients were under ten years of age and an additional 31 per cent were between ten and nineteen years old. Seventeen per cent were in the third decade. Cases of medulloblastoma again showed the highest incidence of increased markings, over 62 per cent. Thirty per cent of cases of astrocytoma, 30 per cent of cases of ependymoma, 11 per cent of cases of oligodendroglioma and 5 per cent of cases of glioblastoma showed some increase.

Increased Vascularity. Increased vascular markings were found in a small number of cases of glioma. Only 7 cases of glioblastoma, 3 cases of astrocytoma, 2 cases of ependymoma and 1 case of oligodendroglioma showed them.

Meningiomas

Seventy-one per cent of the 154 meningiomas in this series showed some evidence of their presence on the roentgenogram.

Calcification. The calcification in meningiomas varied somewhat from that seen in other brain tumors as it was frequently masked in part by the accompanying hyperostosis. Calcium was present in 29 of the 154 cases, an incidence of 18 per cent. It was sometimes deposited in flocculent or punctate masses and gave well defined shadows which could be seen microscopically as psammoma bodies. These shadows often become conglomerate, giving the appearance of a dense calcareous mass of irregular outline.

In 11 of the cases of meningioma in which calcification occurred there was no accompanying hyperostosis of the skull. The site of the tumor seemed to have no influence on whether or not hyperostosis would accompany the calcification. Eighteen of the calcified meningiomas were associated with proliferation of bone. Ten of those which were located in the vault of the skull showed a combined proliferation of bone and calcification. Eight of those located at the base of the skull occurred in conjunction with hyperostosis.

Changes in Bone. Some type of bone reaction was seen in 64 of the meningiomas. Five meningiomas showed actual destruction of bone, and 14 showed erosion of bone by contiguous tumor. Many of these were in conjunction with tumors located in the basofrontal region, especially about the orbit. In some the destruction was associated with concomitant proliferation.

The peculiarity of meningiomas in producing bone in the skull adjacent to their site is the reason for the relatively high degree of localization that is possible in analyzing roentgenograms from cases of this kind. Almost a third of the meningiomas (51) caused bony proliferation. This was either in the inner or outer table or both. In some cases the proliferation consisted of formation of osteomas; in others it was prone to be a hyperostosis and thickening of the bone, occasionally with formation of bony spicules in the involved region.

In general, the meningiomas took one of two forms, as was first described by Cushing[19] and later elaborated by Camp.[13] One type consisted of large growths which were irregularly lobulated and tended toward a rounded shape; the other type was relatively flat, "en plaque," and was inclined to spread over the inner surface of the dura. This latter type was the one most frequently associated with actual bony thickening and hyperostosis. It was found most often at the base of the anterior and middle fossae. Twenty-seven in this series were located in this region. Twenty-four in which the bone was affected occurred in the vault. Meningiomas in the vault, and especially those located parasagittally, were more likely to be associated with actual osteomas than those in the base. Of the 24 in the vault 11 formed osteomas. Among the 27 in the base only 5 presented true osteomas. The remainder caused thickening and increased density of the adjacent bone. Increased vascularity in the region of the osteomas aided in differentiating them

from benign osteomas. The latter were seldom accompanied by increased vascularity.

Meningiomas causing minimal changes in the anterior fossa could be easily overlooked in a roentgenogram in which the details were obscured by motion or inferior technique. Occasionally, tiny flecks of calcium would lead the examiner to closer scrutiny of the bone. Changes resulting from meningiomas of the olfactory groove or the tuberculum sellae most often conformed to those described by Camp, "formation of osteoma at the point of origin of the tumor; localized erosion of the cribriform plate of the ethmoid bone, wings of the sphenoid bone, the sulcus chiasmaticus and the tuberculum sellae; erosion of the posterior clinoids; enlargement and erosion of the sella turcica; and calcification within the tumor."

Erosion of the Sella Turcica. Erosion of the sella turcica occurred in 56 cases of meningioma or in about 36 per cent. The floor of the sella was most commonly eroded; the posterior clinoids were next most commonly affected, and in a much smaller group the anterior clinoids were involved. In some cases of meningioma arising from the floor of the anterior fossa, for example, olfactory groove meningiomas, the anterior clinoids were increased in density. The proliferation of the bone along the floor of the skull extended into the clinoids, giving the appearance of a tiny osteoma arising from the region of the tuberculum sellae. The sella turcica was not necessarily eroded even though the anterior clinoids were involved in the proliferative process.

Other Signs. Separation of the sutures was not found in any cases of meningioma. Only 3 cases showed increased digital markings. Nineteen cases or over 12 per cent were accompanied by increased vascularity on the side of the tumor. The pineal was displaced in 37 cases.

Location. One hundred and thirty-nine of the meningiomas were located supratentorially. Forty of these were located parasagittally, mostly in the frontal or parietal regions. An additional 21 were located in the vault of the frontal region, 23 in the parietal region, 9 in the temporal region, and 6 in the occipital lobe. Thirty-one were located in the basofrontal region, taking origin from the wings of the sphenoid bone, the tuberculum sellae, or the olfactory groove. The middle fossa contained 9. The remaining 15 meningiomas were infratentorial.

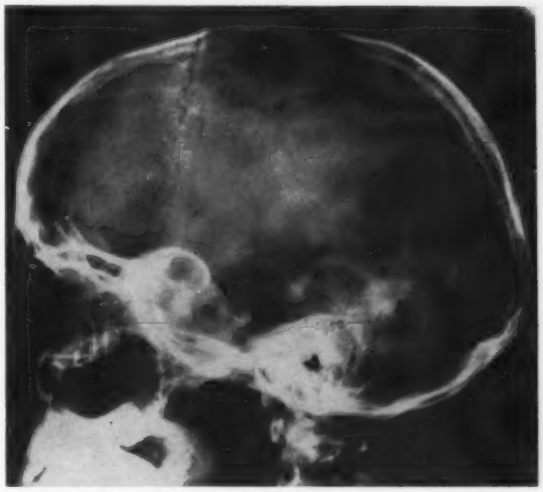

Fig. 9. Fibrosarcoma. Basofrontal region; expansion of bone and secondary deformity of sella turcica. Male, eleven years of age.

Chromophobe Adenomas of the Pituitary

Each of the 29 tumors of the pituitary gland was a chromophobe adenoma. In a few instances, there were areas of eosinophilic activity in the specimen, but no tumors which were predominantly eosinophilic in character were included. Patients with acromegaly due to eosinophilic pituitary tumors frequently respond more satisfactorily to roentgen treatment than to surgery. Thus, almost all of these tumors are treated non-surgically, therefore none was included in this study.

Ninety-five per cent of the cases showed some degree of erosion of the sella turcica. Intrasellar tumors expanded the sella turcica in a uniform circular manner by erosion of the floor and clinoid processes. During the process of erosion the dorsum first became concave on its anterior surface; later it became straight and thin. In the

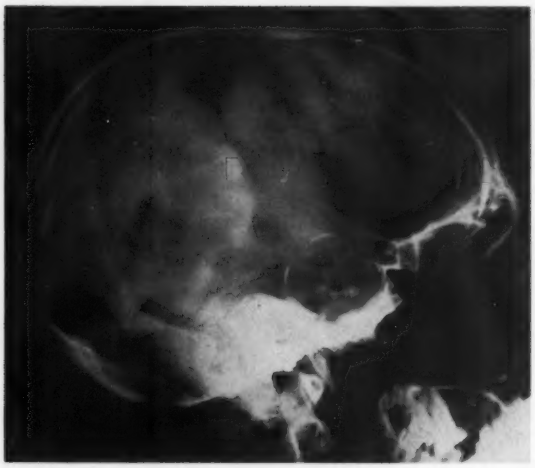

FIG. 10. Pituitary chromophobe adenoma. Curvilinear calcification in a recurrent adenoma. Male, thirty-six years of age.

final stage there was complete destruction of the dorsum. If this had already occurred when the roentgenogram was made, it was difficult for the examiner to determine whether the tumor was extrasellar or intrasellar in origin, since the typical ballooned shape of the sella turcica was lost. Erosion of the dorsum was noted in each of the 95 cases. In all but 4 of these, erosion of the floor was also noted. Early changes in the floor were manifested by fuzziness of the outline. Eventually, the entire floor between the pituitary gland and the sphenoid sinus was destroyed. At times one side of the sella turcica was more involved than the other.

Destruction of the anterior clinoids began by thinning of the under surface, thus helping to give the sella turcica the expanded ballooned shape. The anterior clinoids were eroded in later stages of the tumor growth and were found affected in over half of the cases.

Calcification in chromophobe adenomas of the pituitary was found in 4 per cent. The calcium was deposited in a fine, curvilinear line outlining the periphery of the cyst. This must be differentiated from calcification in an aneurysm of the carotid artery. The most reliable differential point was that, although the aneurysm caused erosion of the sella turcica, the erosion tended to be all on one side leaving the other side intact. Pituitary tumors, although they might affect one side more than the other, tended to be more uniform in their erosion.

An upward displacement of the pineal gland was seen in 7 cases of pituitary tumor. No lateral shift of the pineal gland occurred.

Craniopharyngiomas

The diagnostic accuracy in regard to craniopharyngiomas was relatively high. Seventy-six per cent of the 25 cases showed positive findings. Calcification, which was present in 68 per cent of the cases, was the most characteristic finding along with erosion of the sella turcica or in the region about the sella turcica. The erosion of the sella turcica by itself might not have led one to suspect a craniopharyngioma or Rathke's pouch tumor. However, the occurrence of calcium in a tumor situated in, or in the region of, the sella turcica, with resulting erosion was most apt to be a Rathke's pouch tumor. This was particularly the case if the patient was in the first three decades of life. Calcification in chromophobe adenomas of the pituitary was rare in comparison.

The erosion of the sella turcica simulated either intrasellar or suprasellar erosion, depending on the exact origin of the tumor. More frequently the sella turcica was somewhat flattened from above as if by a suprasellar lesion. One lesion which simulated a Rathke's pouch tumor was a cholesteatoma located in the region of the sella turcica. This type of tumor might also be calcified, but it occurred less frequently than the craniopharyngiomas.

Neither erosion of bone, other than that in the region of the sella turcica, nor pineal shift was seen. Two patients showed some separation of the sutures.

Carcinomas and Sarcomas

Relatively few metastatic lesions were included in this survey since most of them

were too obvious to require surgical intervention, so, unless an autopsy examination was made, pathologic proof was not available.

There were 9 cases of intracranial metastatic carcinoma. Five of these showed positive findings on the roentgenogram. Calcification was absent from each one. Accurate localization was possible in only 1 case in which bone destruction was present. In this case the metastasis was secondary to hypernephroma. Three cases showed some displacement of the pineal gland. Two of the cases showed very early erosion of the floor of the sella turcica.

Sarcomas, most of them undifferentiated as to type, comprised 8 of the cases. Five of these showed positive roentgenologic signs. No calcification was seen in any of these. Three showed some erosion of the sella turcica. Destruction of bone was noted in 2 cases. In 1 of these the pineal gland was displaced.

Of 5 fibrosarcomas, 2 caused changes which could be seen in the roentgenogram. One of these appeared to have originated in a fibrous dysplasia of the skull. In this case there was a bone-like mass located at the base of the anterior fossa together with some increased density of the floor of the skull. The well defined expanding mass caused some deformity of the anterior clinoids of the sella turcica, but did not cause erosion of the sella turcica. In the other case roentgenograms showed destruction of bone in the region of the orbit.

The parietal region was the site of most frequent involvement by metastatic lesions. The frontal region was second in frequency of involvement. The remainder of the lesions were scattered throughout the cranium.

Hemangiomas, Angiomas, Hemangioblastomas

Eighteen intracranial tumors of a hemangiomatous nature were observed in this series. Roentgenograms of 8 cases showed positive findings. Four of these tumors indicated their presence by a shift of the pineal gland. None showed calcification. Erosion of the sella turcica occurred in 6 cases. The digital markings were considered to be increased in 4 cases. No tumor caused separation of the sutures.

Two hemangioendotheliomas in the cerebellum caused erosion of the petrous pyramid on the involved side, and one hemagioendothelioma in the cerebellopontine angle caused destruction of the petrous pyramid. Irregular areas of destruction or erosion of the skull were seen in the vicinity of the tumor in 3 cases.

The majority of hemangiomatous tumors arose in the infratentorial region, 12 of the 18. The remainder was distributed throughout the brain.

Epidermoids

Intracranial epidermoids made up 9 of the total number of the group or less than 2 per cent. A very high percentage of positive findings was encountered. Only 1 did not show some evidence of its presence on the roentgenogram. This one was located in the region of the sella turcica. Calcification was seen in 3 tumors, 2 of which were located in or near the sella turcica. Erosion of the sella turcica was present in 4 cases including both in which calcification was seen.

Three cases presented rather regular cyst-like areas of decreased density in the bone which have been described as typical of epidermoids. These areas have a fairly well defined border and are sharply delimited from the rest of the skull. In all 3 cases the tumor extended into the intracranial cavity.

Of the 7 epidermoids which were supratentorial, 6 were located in the anterior fossa, most of these in the region of the sella turcica. Two of the epidermoids were infratentorial.

Miscellaneous Group

This group includes rare tumors. One tuberculoma was encountered. It gave no evidence on the roentgenogram of its presence. Two chordomas caused very extensive

destructive changes of the base of the skull in the region of the sella turcica. The xanthoma which was seen caused some erosion of the sella turcica and separation of the sutures. Four porencephalic cysts were seen. One caused a displacement of the pineal body. Erosion of the inner table of the parietal bone and erosion of the sella turcica were each observed once.

CONCLUSION

Some indication of an intracranial lesion was present in approximately two-thirds of the roentgenograms reviewed. Tumors of the pituitary gland produced the highest incidence of localizing signs.

Gliomas constituted slightly less than half of all the tumors. Positive roentgenographic findings were noted in 53 per cent of these cases. Calcification, if present, was the most important localizing sign. The appearance of the calcification varied with the type of the tumor.

By correlating the age of the patient with the appearance of the calcium, certain deductions could be made as to the histopathology of the tumor. If the calcium deposition was strand-like in character and the patient over forty years of age the chances of the tumor being an oligodendroglioma were very good. This was particularly true if there was erosion of the inner table of the skull in the region of that tumor. A similar type of calcification in a patient under forty years of age indicated the presence of an astrocytoma. Punctate areas of calcification were seen in spongioblastomas and ependymomas. The latter were found to occur almost entirely in patients who were in the first three decades of life, whereas spongioblastomas were usually seen in older individuals.

It was possible in a high percentage of cases in which a meningioma was present to locate and recognize the type of tumor because of the presence of hyperostosis in the bone, whether or not calcium was present in the tumor. This calcium was deposited in punctate masses in some cases, but frequently the associated change in the adjacent bone made the diagnosis relatively obvious. When there was no change in the bone the calcium was found in the sites where this type of tumor occurred most often, *i.e.*, in the parasagittal or basofrontal regions, or immediately beneath the meninges over the hemispheres. Few patients with calcified meningiomas were less than forty-five years of age. The calcification in the gliomas tended to be situated more deeply within the hemispheres than that in the meningiomas.

Calcification in craniopharyngiomas was also punctate or flocculent in character, but here again the site of the calcium and the younger age of the patient was an important aid in the diagnosis.

Digital markings were found in many of the younger patients. However, since these markings were not infrequently seen in the skull of a normal child, this finding was not considered to be significant unless it was accompanied by other signs of a lesion. Increased vascularity was most frequently associated with meningiomas, but again, owing to the variation in the degree of vascularity in the skulls of normal individuals, this sign by itself was not considered reliable. Secondary erosion of the sella turcica and separation of the sutures indicated increased intracranial pressure, but were not localizing signs. Displacement of the pineal gland gave a general impression as to the site of the tumor, but otherwise did not substantially aid in localization.

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MYELOGRAPHY OF COMPLETE SPINAL OBSTRUCTION*

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AMONG 196 consecutive myelograms obtained at the Cleveland Clinic during the years 1949 to 1953, inclusive, complete obstruction of the spinal canal was encountered in 75, or 38.8 per cent. The 75 obstructions were demonstrated in 73 patients. In each of 2 patients there occurred two episodes of block. One patient with obstruction by a neurilemmoma had recurrence of the tumor, producing a second block 18 months after the first. Another patient from whom a neurilemmoma was removed was found shortly afterward to have obstruction by a metastatic adenocarcinoma.

Because a complete spinal block almost always connotes an emergency necessitating prompt surgical treatment to prevent the patient's suffering prolonged or even permanent disability, all but 1 of these patients had immediate laminectomy, thus providing us with an opportunity to verify or refute the roentgen findings. The only patient who did not undergo surgery was a man with a recurrence of a tumor which had been diagnosed ten months previously at laminectomy as a dumb-bell tumor of the lower thoracic spine, and by histopathologic examination as a hemangiopericytoma. At the time of myelography a complete block from recurrence of the tumor was demonstrated. Since surgery was thought to be of little value in this circumstance, roentgen therapy was instituted. This treatment, however, proved ineffectual, and the patient remained paralyzed.

INDICATIONS FOR MYELOGRAPHY

Myelography is not always necessary to establish the presence of block of the spinal canal. To the contrary, the majority of such conditions are readily recognized by neurologic signs indicative of definite sensory or motor levels—or, if the clinical examination is not conclusive, by examination of the cerebrospinal fluid. A lumbar puncture is usually sufficient to ascertain the presence or absence of a block; if it is not, a combined procedure may be employed by making taps above and below the level suggested by clinical study and comparing the dynamics and the compositions (particularly the protein contents) of the fluids drawn from the two sources. The easiest points of aspiration for the combined procedure are the lower lumbar spine and the cisterna magna. Since these two points are at opposing extreme limits of the spinal canal, more definitive determination of the *level* of obstruction, which must be known for surgical treatment, sometimes must be made by myelography.

In the presence of definite clinical signs localizing the lesion to a particular level, myelography is not indicated. Although ethyl iodophenylundecylate (pantopaque) is a relatively harmless contrast medium, early optimism as to the possibility of its being absorbed from the spinal canal has not proved justified, and the material has been found to produce definite clinical and pathologic reactions.[6,14] Its use at the Cleveland Clinic, therefore, is limited to those cases in which clinical or laboratory findings are sufficiently conflicting that, before surgery is undertaken, additional information is necessary relative either to the localization or to the nature of the lesion. In intervertebral disk protrusions, for example, the clinical signs frequently incriminate a definite lumbar interspace. If they do not, diskography with iodopyracet is frequently very productive of information, and is accompanied by a very low morbid-

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ity. Myelography, therefore, has become almost a "court of last resort."

Occasionally, pantopaque reveals an apparently complete obstruction of the spinal canal when lumbar puncture shows no block, or, at most, a partial block. Since pantopaque has a greater viscosity than the cerebrospinal fluid, the medium apparently is arrested in small spaces in the subarachnoid through which the cerebrospinal fluid has relatively little difficulty in passing.

In the five-year period in which our myelograms provided guidance for laminectomy 195 times, the surgical procedure was undertaken without benefit of myelography 494 times. Thus, 28.3 per cent of our 689 laminectomies were preceded by myelography.

METHOD

The fact that 38.8 per cent of our myelograms revealed complete obstructions is an indication of the seriousness of the conditions in which the procedure was utilized. The medium was used to provide the surgeon with as much information as possible prior to operation. The examinations were undertaken also with the assurance that in many cases, if the contrast medium could not be successfully aspirated at the completion of myelography, it could be removed at the time of surgery, and therefore need not provide a potential source of irritation to the meninges in the years to come.

The amount of pantopaque used in the procedure varies according to the indication for the examination. In the examination of the lumbar subarachnoid space, 6 cc. is usually ample to obtain satisfactory filling of all parts. If it is the cervical region which is being investigated, a greater amount, usually 9 cc., is helpful in getting the column of medium into the region without its breaking up into a series of discrete drop-

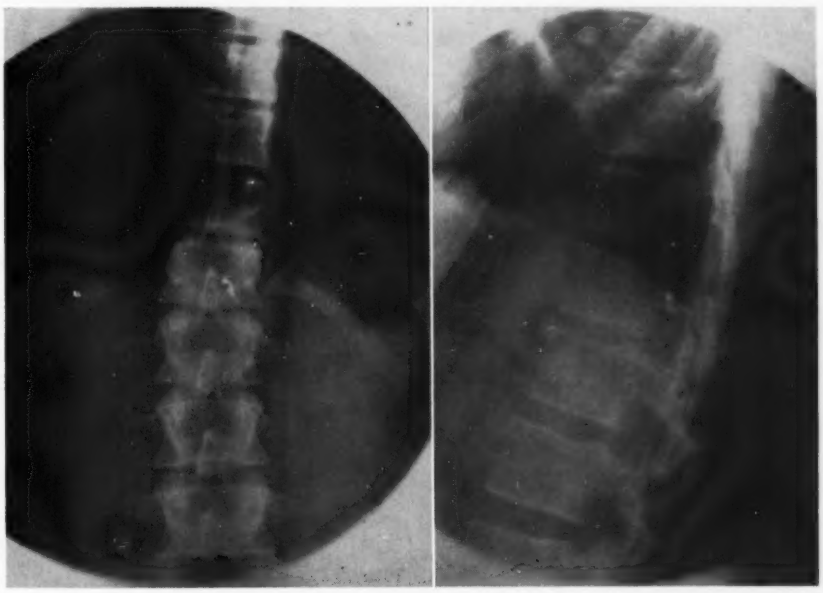

Fig. 1. A twenty-eight year old man, a laborer, had experienced intermittent pain in the back and right sciatic distribution for four years. He had been unable to work because of the pain which was aggravated by coughing, sneezing, or having a bowel movement. For three and one half months prior to admission he had been unable to lie flat, and had been sleeping in a chair. At admission lumbar puncture showed no block. The cerebrospinal fluid was xanthochromic but clear, and its aspiration immediately reproduced the severe pain. Although the specimen clotted, the protein level was determined to be 500 mg. per cent. It seemed obvious that the patient had a spinal cord tumor. A drop of pantopaque introduced into the cisterna magna is seen on the myelogram to have been arrested in its downward course opposite T 12. An intradural tumor $3\frac{1}{2}$ by $2\frac{1}{2}$ by $1\frac{1}{2}$ cm. was found attached to a caudal nerve root, and was removed. The pathologic diagnosis was neurilemmoma.

lets. In many instances an amount sufficiently large to outline the contour of the obstruction is not necessary, and the neurosurgeon finds that a fraction of a cubic centimeter is sufficient for localizing the point of obstruction. For example, in cases where the clinical picture points to a clear-cut tumor but no localizing signs are found on plain roentgenograms, the location of the tumor may be definitely ascertained by placing a drop of pantopaque in the cisterna magna with the patient in a sitting position, and then identifying the exact site of arrest of that drop with anteroposterior and lateral roentgenograms. An example of such roentgenograms is reproduced in Figure 1.

INTERPRETATION OF SPINAL BLOCKS

Among the 75 complete obstructions, the block occurred most frequently in the thoracic portion of the spine. Forty-one myelograms revealed obstruction at that location, an incidence of 54.7 per cent. The lumbar spine was next in frequency with 27 blocks, followed by the cervical with 6, and the sacral with 1 (an ependymoma). Seventy-four of these obstructions were verified at surgery; the only one not surgically verified was previously discussed.

Two other diagnoses of complete block were made in the five-year period, but were found to be in error. In one of the 2 cases the column of pantopaque did not descend below the level of the third lumbar interspace, and the myelogram was interpreted as showing a complete obstruction at that level. The patient had had exploration of his fourth and fifth lumbar interspaces for a protruded disk six months previously, with negative results. On this occasion the surgeon found a somewhat prominent third lumbar disk, which, however, was not considered to be sufficient to cause a block. No obstructing lesion was present. Possibly there was an irregularity of shape of the spinal canal resulting from the previous surgery which led us to think that we were dealing with an obstruction.

The other false positive diagnosis of complete obstruction occurred in a man fifty-seven years of age with rather large osteoarthritic spurs on the lumbar vertebrae. The major part of the opaque medium injected into the cisterna magna did not descend lower than the third lumbar interspace, but small collections of pantopaque did get by and were held up at the fourth lumbar and lumbosacral interspaces. The osteophytic spurs were about equally prominent at each of these interspaces. Since the medium was not completely arrested at the third interspace, a diagnosis of obstruction should not have been made. Exploration showed no disk protrusion at any of the suspected levels, but only the arthritic spurs.

In Table 1 a list of the pathologic conditions found to be responsible for block of the spinal canal is given in descending order of frequency. To our surprise we found that in this series intramedullary causes of obstruction were almost insignificant in comparison with the great number of extramedullary causes. Only 3 obstructions due to intramedullary lesions occurred in the 75

TABLE I

DIAGNOSES AT LAMINECTOMY IN DESCENDING ORDER OF FREQUENCY

Diagnosis	No. of Cases
Neurofibroma (neurilemmoma)	15
Intervertebral disk protrusion	12
Meningioma	11
Arachnoiditis, adhesions	6
Carcinoma	5
Lymphoma	5
Hemorrhage, hematoma	3
Multiple myeloma, plasmacytoma	3
Tuberculosis	3
Sarcoma	2
Syringomyelia	2
Diastematomyelia	1
Ependymoma	1
Hemangioma	1
Hemangiopericytoma	1
Subluxation of vertebrae	1
Teratoma	1
Transection of cord	1
Tumor, type undetermined	1
Total	75

FIG. 2. A fifty-nine year old man had had 2 laminectomies three years prior to admission because of severe pain in the back and left leg. Despite these operations the pain had persisted with such intensity that the patient had attempted suicide. At admission lumbar puncture could not be carried out at L 4 or L 5 because of the tenderness of the spinous processes. Puncture was finally accomplished at the L 1 space, where no abnormality was encountered. The cerebrospinal fluid protein content was 33 mg. per cent. One cubic centimeter of pantopaque was introduced through the lumbar puncture needle; the films show a complete obstruction opposite L 1. At laminectomy the arachnoid was found to be greatly thickened along the entire length of the cauda equina. In order to relieve the patient's pain a topectomy was done; results were very satisfactory.

cases, an incidence of 4 per cent. Actually, even this figure is high, for 2 of the cases considered as having an intramedullary condition were patients with syringomyelia, in whom the obstruction appeared to be the result of associated arachnoid adhesions rather than actual expansion of the cord.

The remaining instance of intramedullary obstruction is the one case in the entire series of which we have no histologic proof. At laminectomy a tumor was found at T 12, and the cord decompressed at that location. No biopsy was performed, but the tumor was presumed to be a glioma. It is noteworthy that, except for this unproved case, we have no example of a glioma among our 75 obstructions. Probably gliomas are less prone than neurofibromas and meningiomas to cause complete obstruction.

In the spinal cord the proportion of tumors of the supporting tissue to those of the investing tissue apparently is inverse to that proportion encountered in the brain. Among brain tumors, gliomas are much more frequent than meningiomas. Spinal tumors, however, show a preponderance of neurofibromas and meningiomas, probably because in the spinal cord there is relatively a much greater amount of meningeal and nerve root tissue than of glial tissue.

FRAGMENTARY VERSUS ABRUPT BLOCKS

In many instances it is possible to determine the cause of obstructions resulting from extramedullary lesions by observing the movement of the contrast medium in the subarachnoid space, and the outline of the column as it comes to rest against the obstructing agent. If the contrast medium moves slowly and hesitatingly, and breaks up into separate globules at different levels, subarachnoid adhesions are a likely explanation. In our series there were 6 such cases, most of whose adhesions were the result of previous surgery (Fig. 2 and 3) or myelog-

raphy or both. In one patient without a history of previous surgery the adhesions were considered to be the result of old trauma which produced some compression of the vertebrae. In addition to these cases, the series includes 2 patients with syringomyelia, whose obstructions were apparently due to arachnoiditis (Fig. 4). Adhesions were also responsible for the broken-up appearance of the medium in the case of a five year old boy, the lower half of whose body had been paralyzed since an automobile accident nine months earlier (Fig. 5). Laminectomy revealed complete transection of the cervical cord with separation of the parts by a distance of 1 to 1¼ inches.

In contrast to this fragmentary distribution of the pantopaque, the abrupt termination of the column is found in many conditions. Usually it is possible to determine from the appearance of the column whether the block is due to an intradural or extradural cause, if not the exact nature of the blocking agent. If the end of the pantopaque column takes a concave form as it partially encompasses the obstruction, that obstruction is almost certain to be intradural. If, on the other hand, the column frays out or is funneled into a narrowing channel—almost always in an eccentric position in the vertebral canal—there is a very strong probability that the lesion is of extradural origin. Various types of conditions producing these abrupt spinal obstructions will be discussed.

INFECTIONS

Tuberculosis is by far the commonest type of infection that causes spinal block. Our experience in this series is limited to 3 cases of tuberculosis. The most constant distinguishing feature of these cases was the presence of narrowing of the involved intervertebral space. In 2 instances the site was the fourth lumbar disk and in the other it was the ninth thoracic. However, in one of the patients with lumbar tuberculosis, the narrowing was not evident when the patient was first seen (Fig. 6). The man gave a history of trauma and exhibited

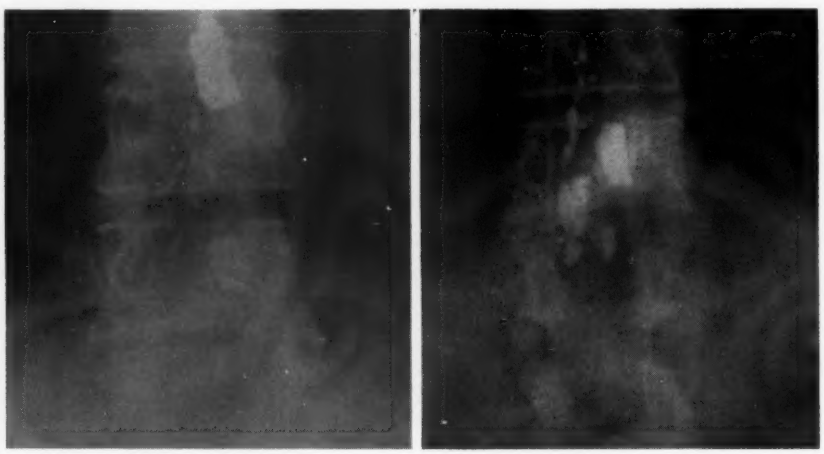

Fig. 3. A thirty-eight year old fireman had fallen while carrying a woman down a ladder twenty-two months prior to admission. Seven months after this accident pain had persisted despite conservative treatment, and a laminectomy was done; the patient stated that paralysis of both legs resulted from this operation. At examination 2 or 3 cc. of pantopaque remained in the lumbosacral area from a myelogram performed elsewhere three months previously; this was used to demonstrate that an almost complete block was present at T 12. Attempts at cisternal puncture were unsuccessful; however, a cerebrospinal fluid tap was achieved in the thoracic spine. The protein content here was 42 mg. per cent, that in the lumbar area, 102 mg. per cent. The myelogram obtained after injecting 3 cc. of pantopaque through the thoracic needle shows an irregular distribution of the medium, with complete arrest at L 1. Laminectomy showed the conus medullaris to be bound down by thickened arachnoid. A decompression was done, and the patient had a favorable, although slow, response.

Fig. 4. A forty-six year old woman had experienced weakness and pain of the right leg and hip and a consequent difficulty in walking for the two years prior to admission. She stated that the symptoms had begun after she had undergone a hysterectomy and appendectomy for which she had been given a spinal anesthetic. At admission lumbar puncture showed an initial pressure of 170 mm. Hg, and a protein content of 50 mg. per cent. Queckenstedt's test showed a partial block. Following the puncture she was unable to get out of bed. Sensory impairment pointed to a lesion at T 3, but injection of pantopaque into the cisterna magna showed arrest at T 12, for which level she had no clinical signs. Many droplets of the medium are seen on the myelogram to be scattered along the thoracic spine. At laminectomy at T 11 the spinal cord was seen to be enlarged and somewhat soft and fluctuant. A needle aspiration of the cord, withdrawing 12 cc. of a slightly opalescent, colorless fluid, established a diagnosis of hydromyelia.

findings on physical examination which suggested a disk protrusion causing compression of the fourth lumbar nerve. Diskography was done, and normal-appearing disks were found at the third and fourth lumbar and lumbosacral interspaces. After several months of treatment with conservative measures failed to produce results, a myelogram was made that showed occlusion of the spinal canal by a lesion which appeared to cause "pinching" of extradural type at the level of L 4 (Fig. 7). At laminectomy a large epidural abscess was found anteriorly, extending into the body of the fourth lumbar vertebra, which proved on bacteriologic and pathologic examination to be tuberculous. At the time of the myelogram it can be seen that some slight narrowing of the fourth lumbar interspace had occurred, as well as some destruction of the body.

CONGENITAL ANOMALIES

The only spinal anomaly encountered in our series was a case of diastematomyelia in a one and one-half year old boy who had never learned to walk or to sit normally. Plain films showed a mild gibbus at the thoracolumbar junction, underdevelopment of the upper lumbar vertebrae, which lacked easily recognizable pedicles, and three anomalous ossicles running in a diagonal course posterior to the body of the last thoracic vertebra (Fig. 8). A myelo-

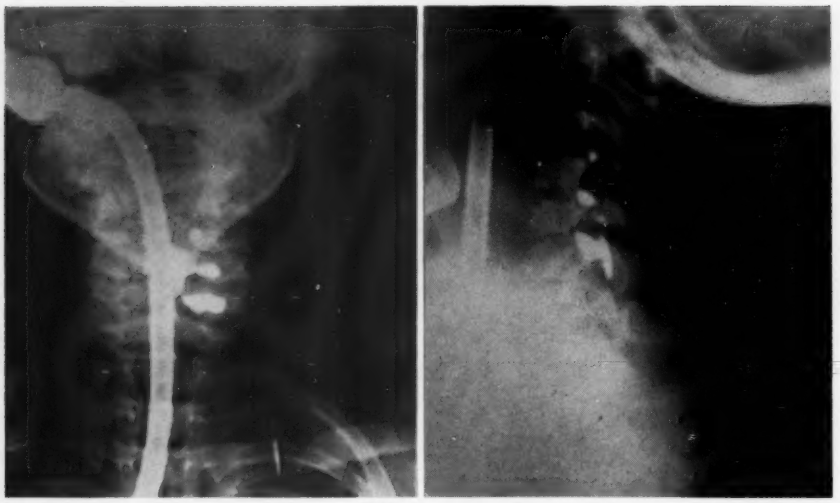

Fig. 5. A five year old boy had had paralysis in the lower half of his body after an automobile accident nine months previously. He was incontinent of bladder and bowel, and body temperature regulation was upset to the extent that in hot weather he ran a fever of 104–105 degrees. Following the accident he had become very obese. His blood sugar levels on several occasions were elevated, but a glucose tolerance test did not yield a diabetic curve. One-half cc. of pantopaque was introduced into the cisterna magna for the myelogram. The films show arrest of the medium at several levels in the lower cervical region. At operation a complete transection of the cervical cord was found, with separation of the two portions by more than one inch. Very dense fibrous adhesions surrounded the traumatized area.

Fig. 6. A twenty-eight year old steel mill worker gave a history of a severe injury nine months previously. He had fallen from a hopper onto an incline, had twisted and squirmed in order to avoid being caught on a conveyor, and then had "passed out" briefly from the severity of back pain. His physical signs pointed to a protruded fourth lumbar disk, but the surgeons hesitated to explore since a lumbar puncture showed no abnormality, films of the lumbosacral spine revealed no abnormal findings, and diskograms of the third and fourth lumbar and all the lumbosacral spaces were normal. He was treated with Buck's traction and a low back brace. The chest roentgenogram was normal. In retrospect, it is possible to distinguish on the original film, which shows no bony disease, the presence of a soft tissue mass overlying the lower part of the left psoas muscle.

gram showed a funnel deformity blocking the canal below the anomalous ossicles (Fig. 9). Laminectomy proved that these ossicles were situated in the space ordinarily occupied by the cauda equina which in this case was split into two portions, flattened out, and attached to the sides of the bony canal.

TUMORS

The spinal canal nurtures relatively few types of benign tumors. In this series were found 1 teratoma, 1 hemangioma, and 1 hemangiopericytoma. Neurofibromas (or neurilemmomas), however, were the commonest cause of obstruction in our series, accounting for a total of 15 cases. These

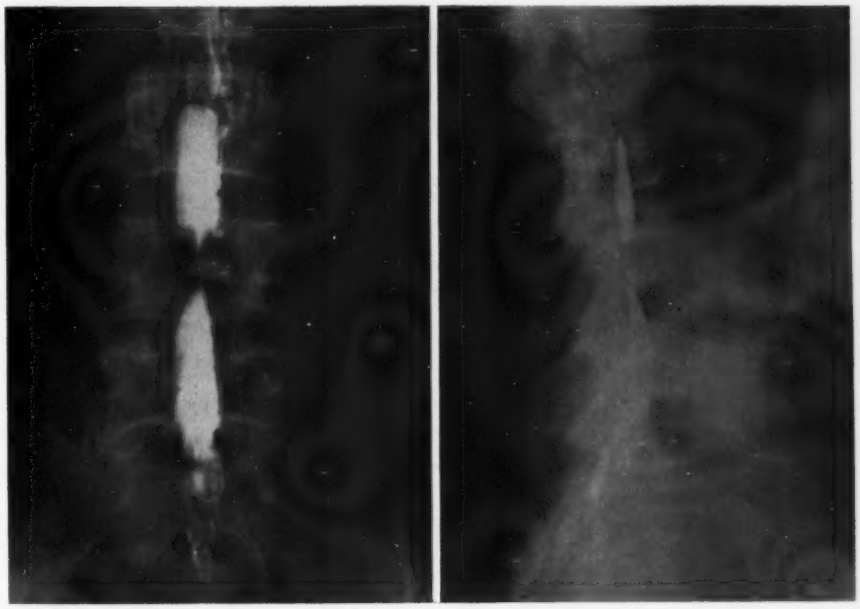

Fig. 7. Myelogram of the same patient as in Figure 6, six months later, showing marked compression of the spinal canal opposite body of L 4. There also had developed some destruction of the lower part of this body, and slight narrowing of the fourth interspace. At laminectomy a large epidural abscess was found anterior to the spinal cord and extending into the fourth lumbar body. Histopathologic and bacteriologic diagnoses were tuberculosis.

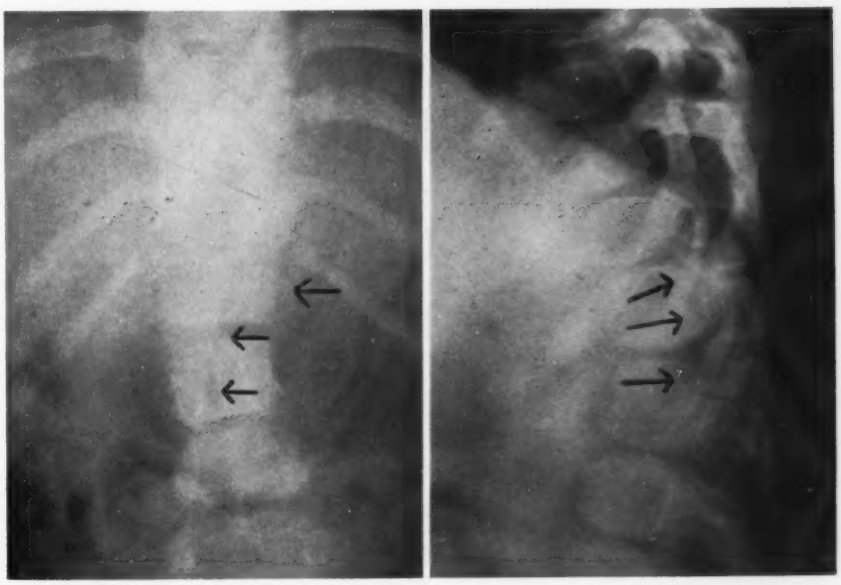

Fig. 8. A one and one half year old boy had had a "lump on his back" since birth. He had never used his legs much, or sat well, and had appeared in recent months to be losing some abilities he formerly had possessed. He had never been able to learn bowel or bladder control. A week before admission he had had a fever, and the doctor who gave him a gluteal injection as treatment discovered an analgesia of the legs. Spinal films show many anomalies of the lumbosacral area. The upper lumbar vertebrae have bodies smaller than normal, and their pedicles are scarcely recognizable. Hemivertebrae are present at T 9. A mild gibbus is present at T 12, and the spinous processes above and below point rather sharply away from this level. Three small, rounded, bony masses are present posterior to the body of T 12 in an oblique course (arrows).

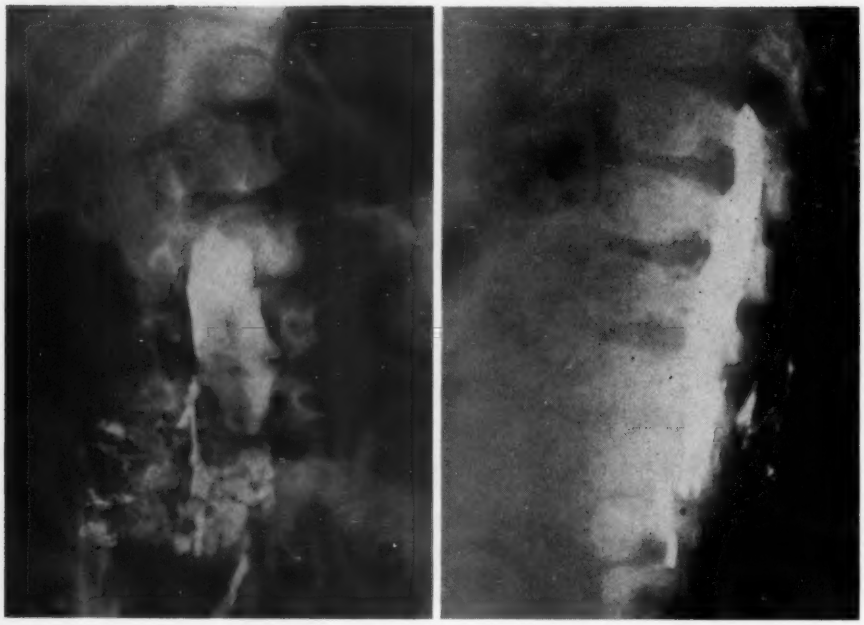

Fig. 9. Myelogram of the same patient as in Figure 8, showing some of the medium in the spinal muscles, but the major part in the subarachnoid space. Cephalad flow was completely blocked opposite the upper part of L 2. At operation the fibers of the cauda equina were found split into two portions that were flattened out and attached to the sides of the spinal canal. The split occurred around a mass of bone $\frac{3}{8}$ inch long which ran in an anteroposterior direction across the spinal canal—an evident case of diastematomyelia.

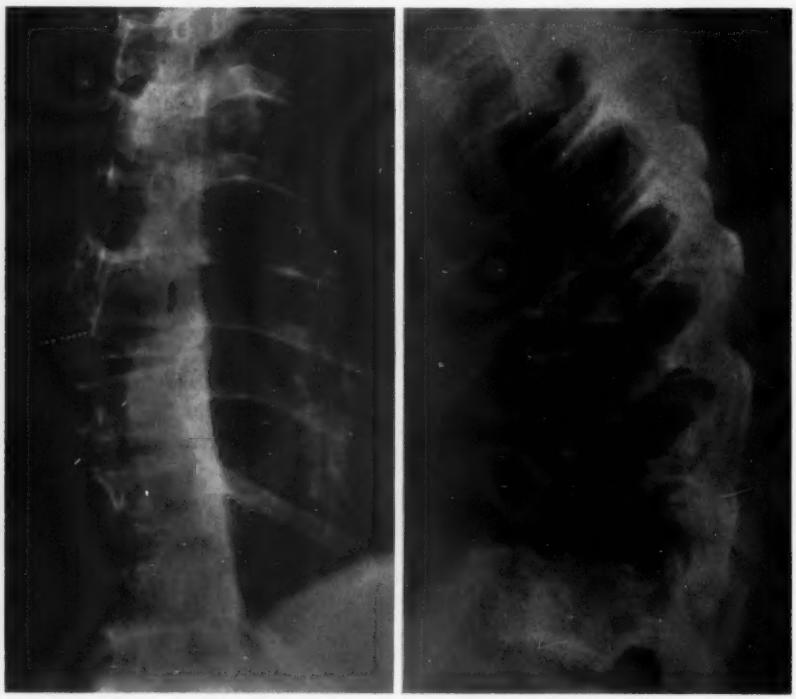

Fig. 10. A forty-five year old woman had had a right radical mastectomy for breast carcinoma fifteen months previously. Pain had occurred in her back for four months prior to admission, and a paralysis had gradually extended from her feet to her waist. Lumbar puncture showed a block. The cerebral spinal fluid protein was 320 mg. per cent. Films of the thoracic spine show marked demineralization of all the bones, with collapse of the body of T 8.

will be discussed under a separate heading, as will meningiomas.

The malignant tumors were fairly well distributed as to type. There were 5 carcinomas, 5 lymphomas, 3 multiple myelomas, and 2 sarcomas. Of the 5 carcinomas, 2 were of the breast (Fig. 10 and 11), 1 of the thyroid, 1 thought to be of the cervix uteri (Fig. 12 and 13), and 1 from undetermined origin (Fig. 23 and 24). The lymphoma group was composed of 3 lymphosarcomas and 2 Hodgkin's granulomas (Fig. 14 and 15). The 3 myelomas were all of the plasmacell variety. Of the 2 cases of sarcoma, 1 was metastatic from a chondrosarcoma of the left ninth rib, and the other appeared to be a primary tumor arising in the meninges.

Meningiomas. Meningiomas usually provide an excellent example of intradural tumors, although on occasion they may arise extradurally. Eleven cases occurred in our series. One occurred in the cervical region, 9 in the thoracic, and 1 in the lumbar. Figure 16 shows a case where a complete obstruction was not present on lumbar puncture, yet none of the medium injected into the cisterna magna passed beyond the tumor. Figure 17 is an example of a myelogram that helped significantly in the differential diagnosis of a lesion at the lower lumbar level. The patient gave a history which appeared typical of a disk protrusion. Lumbar puncture showed no abnormality of dynamics, and only a moderately elevated cerebrospinal fluid protein level. A diskogram showed normal disks at the fourth lumbar and lumbosacral interspaces. Not until myelography was done did it become evident that we were dealing not with a protruded disk but with a tumor. The myelogram indicates that, in spite of the considerable mass of tumor, a complete obstruction was not present, and some portion of the pantopaque is seen in the caudal sac.

Fig. 11. Myelogram of the patient shown in Figure 10 demonstrates a complete obstruction opposite T 9. The defect in the center of the column of pantopaque, of course, represents the spinal cord. The film also shows destruction of the pedicles of several vertebrae, and a soft tissue mass extending to the left of the collapsed vertebra. Decompressive laminectomy was performed.

Fig. 12. A sixty-one year old woman had been treated with radium for carcinoma of the cervix uteri four years previously, and had been considered to be free of tumor. Pain had been present in the low back and hips, however, for nine months prior to admission. Lumbar puncture revealed a block, with faintly xanthochromic fluid. The protein content of the fluid was 140 mg. per cent. The myelogram demonstrates a complete block at T 12. Some irregularities of density can be seen in the vertebrae.

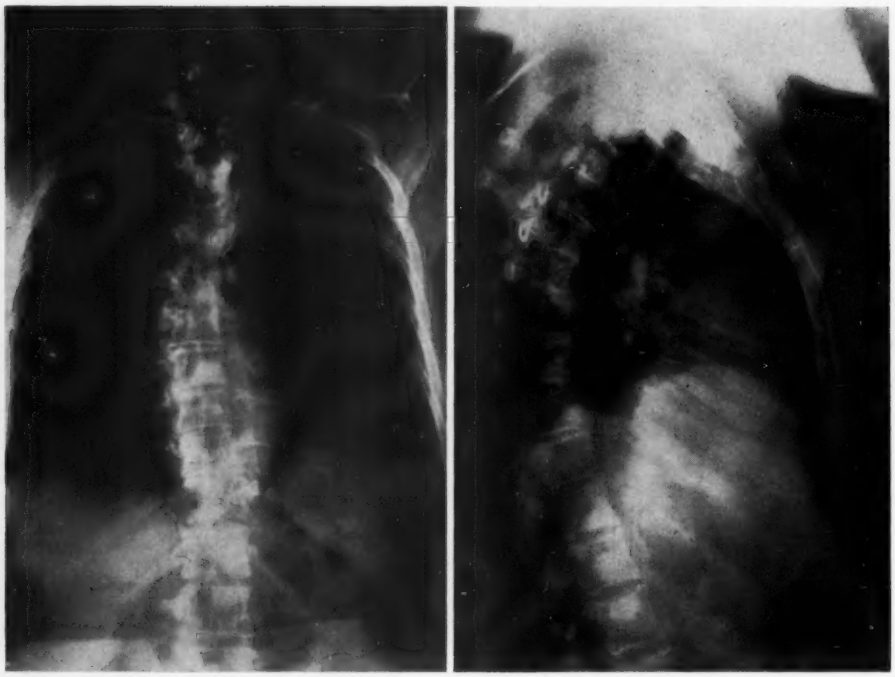

Fig. 13. Thoracic spine of the patient shown in Figure 12. Osteoblastic and osteolytic lesions are widely distributed throughout the bones. At operation widespread invasion of the vertebrae by tumor was encountered, and the cord was decompressed. The pathologic diagnosis was that of osteoblastic carcinoma, most suggestive of squamous cell derivation. The origin of the tumor, therefore, is not absolutely definite, but most probably was the uterine cervix.

The case is included in our series of complete obstructions because at fluoroscopy the obstruction appeared complete, and the medium was seen to pass around the tumor only on the films made later.

Neurofibromas. The commonest lesion in

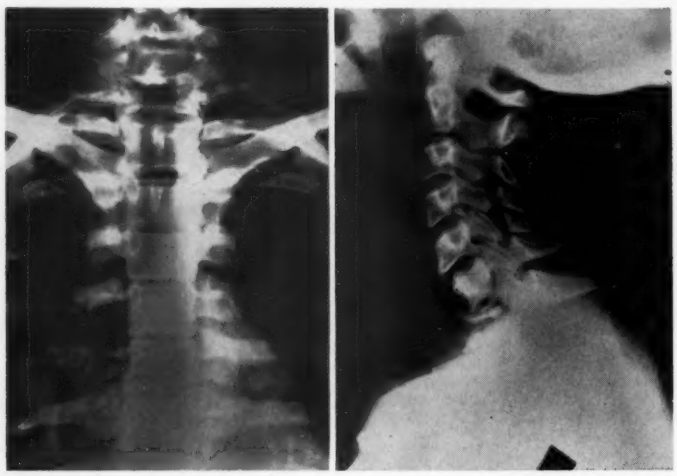

Fig. 14. Cervical spine of a woman who was first seen at the clinic four years earlier, at the age of twenty-three, because of a swelling of the neck which biopsy showed to be an atypical granulomatous lymphadenitis. In the intervening years she had received roentgen therapy to her neck, mediastinum, spine, and epigastrium. Despite the irradiation of the area, collapse is seen to have occurred at T 1. A review of the original biopsy slides resulted in a change of diagnosis to Hodgkin's granuloma.

our series (15 instances in 14 patients) was diagnosed by the pathologist as neurilemmoma. Ten of the tumors arose in the thoracic spine and 5 in the lumbar spine. These tumors may be either intradural or extradural, according to whether they arise from the nerve sheaths before or after they penetrate the dura. If the tumor grows large it may expand outside the vertebral canal, eroding portions of the body or neural arch, or forming a mass extending into the paraspinal area. Such a tumor is seen at T 8 in Figure 18 and 19, and a similar one at T 11 and T 12 in Figure 20. The latter case is classified as an extradural tumor because the myelogram shows a funnel deformity with displacement of the spinal cord to the right anterior portion of the canal, but at operation the surgeon estimated that, of the portion within the vertebral canal, two-thirds was extradural and one-third intradural. Upon removal of this tumor the patient made a favorable recovery but her symptoms later recurred. Eighteen months after her original operation she returned for treatment. Pantopaque was not introduced on her second admission, but the medium remaining in the lumbar canal was used to demonstrate an obstruction by the tumor which was almost identical with that shown on the first myelogram (Fig. 21).

Figure 22 demonstrates the myelogram of a patient whose neurofibroma was intradural. It will be noted that the block was not complete, but that the pantopaque, introduced into the lumbosacral space, traveled around the tumor into the lower thoracic region.

After a cystic neurilemmoma was removed from the level of the third lumbar interspace, the patient made an uneventful recovery until three days after returning home from the hospital, when her legs suddenly became paralyzed. The cause of the paralysis was uncertain and the attending physician considered a diagnosis of hysteria. The patient remained paraplegic and returned to the hospital one month after her initial surgery. In reviewing the original myelograms, it was possible to see evidence

Fig. 15. Myelogram of the same patient as shown in Figure 14. Complete obstruction just below the collapsed first thoracic body can be seen. Laminectomy confirmed the presence of Hodgkin's granuloma.

of bone destruction in the tenth thoracic vertebra, and this was well demonstrated on films made at her second admission (Fig. 23). A myelogram then showed a frayed type of obstruction at this level (Fig. 24). Thoracic laminectomy uncovered an extensive adenocarcinoma eroding the bones and involving the paravertebral muscles.

RUPTURED DISKS

Protrusion of the intervertebral disk was found to account for symptoms in 12 patients. In 2 of these the protrusions were cervical, in 10, lumbar. In the cervical cases the protrusions were demonstrated by block of the pantopaque introduced into the lumbar subarachnoid space—and in both patients the block occurred at the interspace between the sixth and seventh cervical vertebrae. In one of the patients a ruptured disk was found at not only this interspace but also at the one above it.

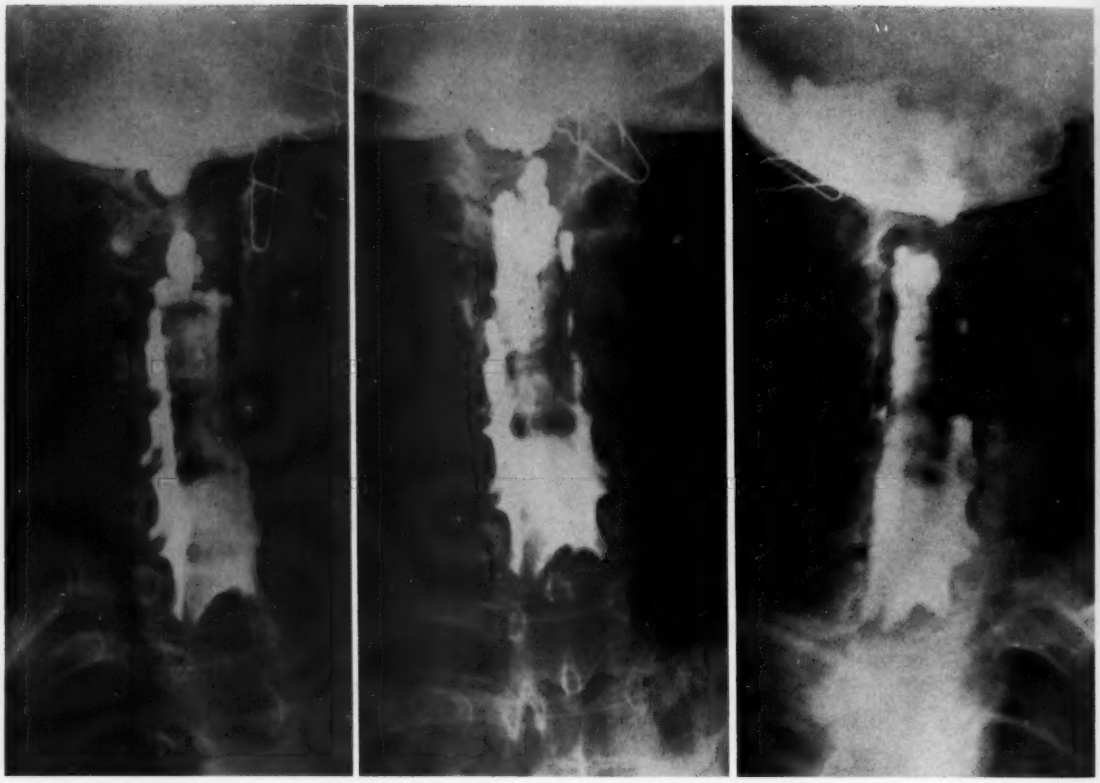

Fig. 16. A fifty-seven year old woman had had pain in the back for six months and recent inability to walk. Sensory impairment was found on the left, below the fifth thoracic dermatome, and a weakness of the left leg. An almost complete block was encountered at lumbar puncture. Myelogram following instillation of 4 cc. of pantopaque into the foramen magnum shows a complete obstruction outlined as a dome, typical of an intradural lesion. A meningioma was found and removed.

Among the 10 patients with blocks due to lumbar disk protrusion, 2 had obstruction at the first interspace, 1 at the second, 2 at the third, 3 at the fourth, and 2 at the lumbosacral space. This distribution is heavily weighted in favor of the upper lumbar interspaces, where clinical experience shows a relatively rare incidence of disk protrusions. In our clinic, as elsewhere, the vast majority of ruptures are found at the fourth lumbar and, especially, the lumbosacral interspaces. Because of our greater experience with lower lumbar protrusions, and because of the rather typical clinical pictures which result from such protrusions, we find it rarely necessary to utilize myelography in such patients. Above the fourth lumbar interspace, disk protrusions become progressively rarer, and as will be seen, more bizarre.

A myelogram showing a very large protrusion at the fourth lumbar interspace is shown in Figure 25. Perhaps because of the unusual size of the protrusion, the clinical picture was far from clear. The patient was a fifty-five year old man with pain in his left leg of nine months' duration. Before he was seen at the clinic, he had been examined by seven other doctors, and had been studied thoroughly during hospitalization elsewhere. Pulsations in the vessels of his legs were weak, and the fact that his leg pain was aggravated on standing suggested claudication. Our orthopedic surgeon believed that the disease was a vascular impairment, and administered a paravertebral block. Such a block had been tried elsewhere without relief, and we also failed to secure alleviation of the pain with this treatment. A lumbar puncture was then

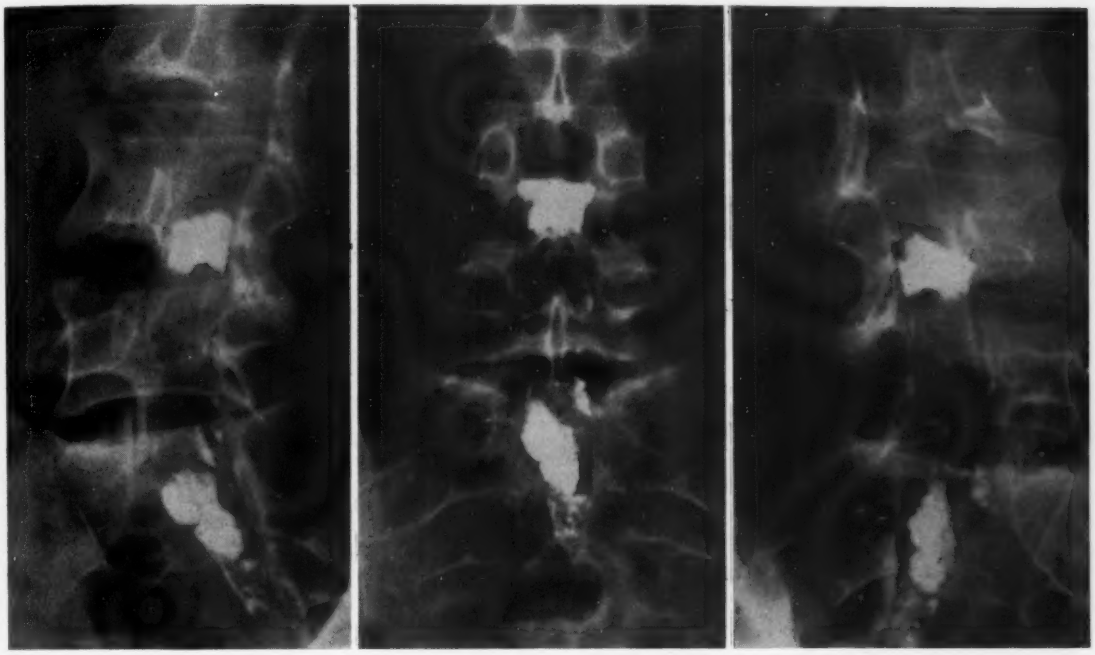

Fig. 17. A thirty-nine year old woman had had pain in the left hip for more than one year, which was aggravated by sneezing and coughing. Lumbar puncture showed a normal pressure and a cerebrospinal fluid protein of 125 mg. per cent. The patient was thought to have a disk protrusion, but diskograms at the fourth lumbar and the lumbosacral spaces were normal. The myelogram shows a rounded defect in the spinal canal opposite L 5, of intradural type, which did not completely obstruct the canal. At operation a small intradural tumor was found which was described as "obviously a neurofibroma," but which on pathologic study proved to be a meningioma.

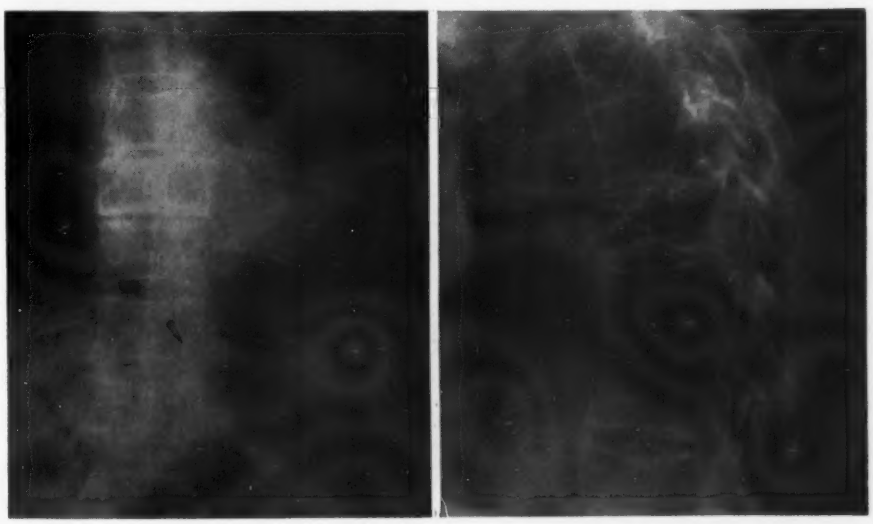

Fig. 18. A fifty-six year old woman had had pain in the left flank for more than five years. Films of the thoracic spine show considerable osteoporosis, and a lesion expanding the body of T 8, eroding the left pedicle of this vertebra, and extending into the left side of the thorax. The films were reported as "consistent with neurofibroma," but the clinician was more concerned with the generalized osteoporosis and treated the patient as a menopausal case. She had had her last menstrual period three years previously, and complained of "very bad" hot flashes ever since. She was fitted with a brace and given stilbestrol and then methyl testosterone.

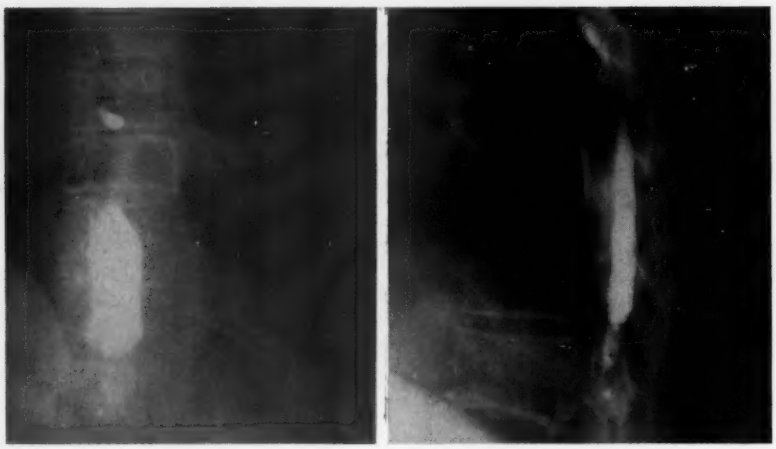

Fig. 19. Myelogram of the same patient shown in Figure 18. When the patient failed to obtain relief of pain on endocrine therapy, attention was focused on the lesion at T 8. Lumbar puncture showed a slightly diminished initial pressure of 145 mm. Hg, and the protein content was 120 mg. per cent. The myelogram shows obstruction at the involved vertebra. The spinal cord is displaced anteriorly and to the right by the extradural tumor. At operation all of the epidural tumor was removed, and the intrathoracic portion delivered in large pieces. The pathologic diagnosis was neurilemmoma.

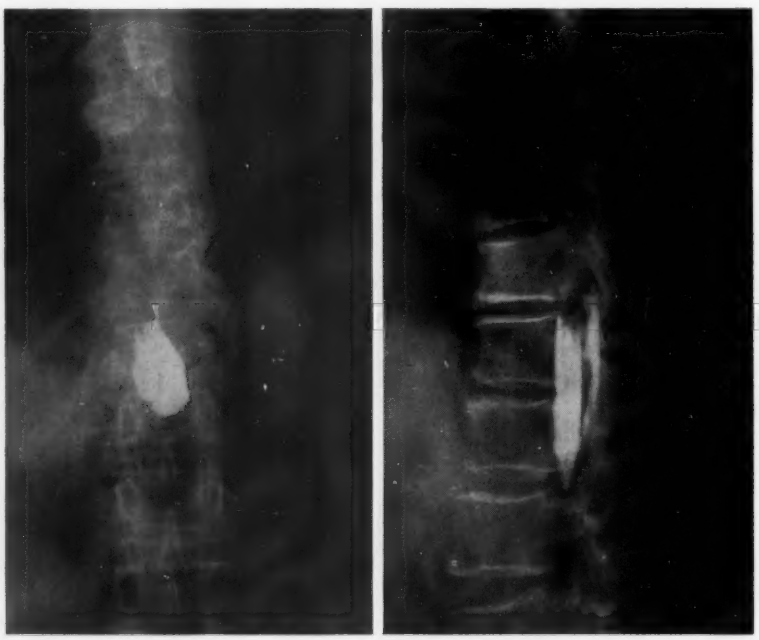

Fig. 20. A sixty year old woman complained of having had pain in the low back and left hip for three years, loss of ability to use her legs for several weeks, and urinary incontinence of one week. The cerebrospinal fluid protein was 297 mg. per cent. The myelogram made following the injection of 3 cc. of pantopaque by lumbar puncture shows a tumor almost identical with that in Figure 19, but obstruction is at T 11. At operation the intraspinal portion of the neurofibroma was removed, but not the extraspinal portion. The intraspinal tumor, described as half the size of an adult thumb, was about two-thirds extradural and one-third intradural. The patient's symptoms cleared rapidly, and a letter from her daughter three months later described the patient's condition as "almost miraculous."

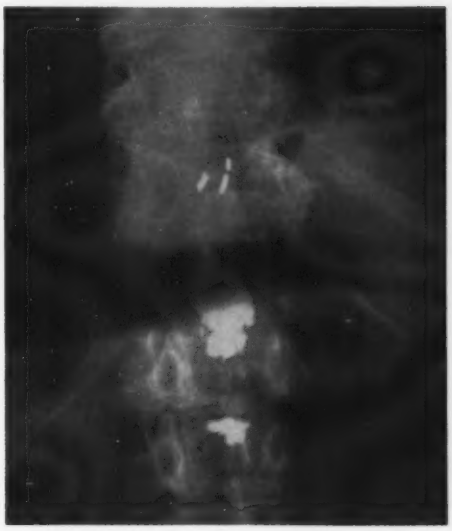

FIG. 21. Myelogram of same patient as in Figure 20, eighteen months later. Her cure was only temporary, and her complaints of pain and buckling of the legs returned. No pantopaque was introduced for this myelogram, but the medium remaining from the myelogram eighteen months earlier shows complete obstruction, with a pattern almost identical with that encountered the first time. The dark band across the left side of the film is an artefact. The silver clips mark the site of removal of the original tumor. The extravertebral mass may be seen to be larger than in Figure 20, and to have caused erosion of the neck of the left twelfth rib and some destruction of the eleventh.

performed at the lumbosacral space, and this showed evidence of obstruction. Only 3 cc. of clear fluid could be obtained. The cerebrospinal fluid protein of this specimen was 67 mg. per cent. At surgery a very large extruded fragment of disk material was found compressing the cauda equina.

Both patients with obstruction at the third interspace presented unusual clinical and myelographic features. One, a sixty-six year old man, had had a previous negative exploration of the lumbosacral space. Pantopaque introduced into the cisterna magna was arrested at the level of the third lumbar

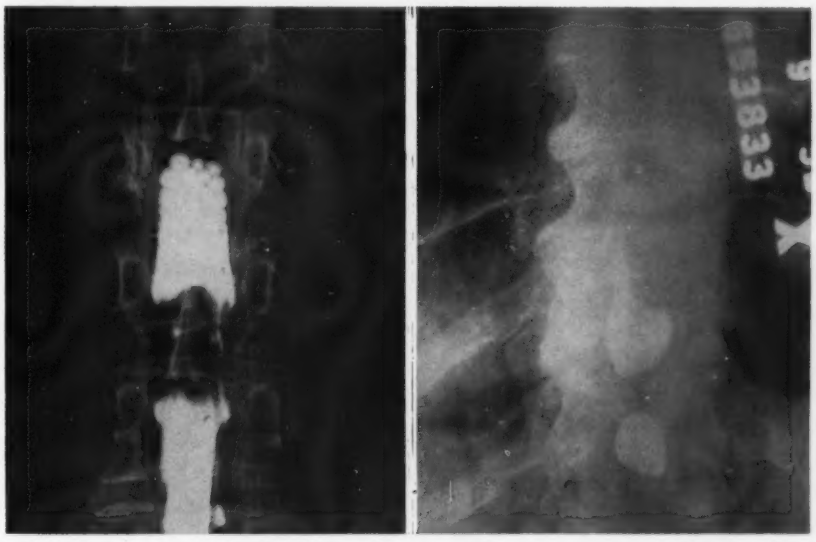

FIG. 22. A fifty-three year old woman had had pain in the left leg for two months. The myelogram demonstrates no complete obstruction, but there is a rounded defect opposite the third lumbar interspace which is typical of an intradural tumor. During fluoroscopic observation the pantopaque was carried to the lower thoracic region. It is possible to see on the second film that there is another rounded defect outlined by the pantopaque at T 11, but in paying attention to the lumbar lesion the thoracic one was overlooked. In retrospect it is also significant that the protein content of the spinal fluid withdrawn at surgery, nine days after the original protein determination of 138 mg. per cent, showed a rise to 245. At laminectomy an intradural tumor was found at the third lumbar interspace, which proved to be a cystic neurilemmoma.

Fig. 23. Thoracic spine of same patient shown in Figure 22. Three days after her return home from the hospital the patient suddenly became paralyzed, was unable to void, and lost control of her bowels. The attending physician was puzzled by the development and considered the possibility of a hysterical reaction. Various treatments failed to produce any improvement, and she returned to the clinic, one month after the original laminectomy, with a flaccid diplegia and a level of sensory impairment at T 9. Attention now was focused on the thoracic spine, where there may be seen destruction of the body and complete loss of the pedicles of T 10.

interspace. Laminectomy showed a very prominent intervertebral disk at this level, which was considered to be the cause of the patient's symptoms through compression of the nerve root. Yet, there was no rupture of the posterior spinal ligament, and it is difficult to understand why the myelogram demonstrated a complete obstruction.

The myelogram of the other patient with obstruction at L 3 is shown in Figure 26. The striking feature of this obstruction is that there is compression of the subarachnoid space from behind, instead of the usual anterior compression produced by a protruded disk. The reason became evident at operation, when the large mass of protruded material was found to be located in the posterior part of the epidural space, with a thin thread of nuclear material passing around the cord to the site of rupture through the posterior longitudinal ligament.

One other patient, in whom we believed we had demonstrated obstruction at the level of the third lumbar interspace, was one of those previously discussed as having false positive myelograms. The disk at this level was indeed prominent, but there was no protrusion, and it was not thought possible for the prominence of the disk alone to be responsible either for the patient's symptoms or for the complete arrest of the opaque medium.

INTRADURAL DISK PROTRUSIONS

The 2 instances of disk protrusions at the first lumbar interspace were the most remarkable of all in that the disk material

Fig. 24. Myelogram of same patient shown in Figures 22 and 23. Lumbar puncture upon re-admission showed a complete block, with xanthochromic fluid, and a protein level of 1,600 mg. per cent. The myelogram demonstrates obstruction opposite the upper part of T 11. Laminectomy showed a huge tumor in the area eroding bone and extending into the surrounding muscles. The histologic structure indicated a metastatic adenocarcinoma, but the primary site was not determined.

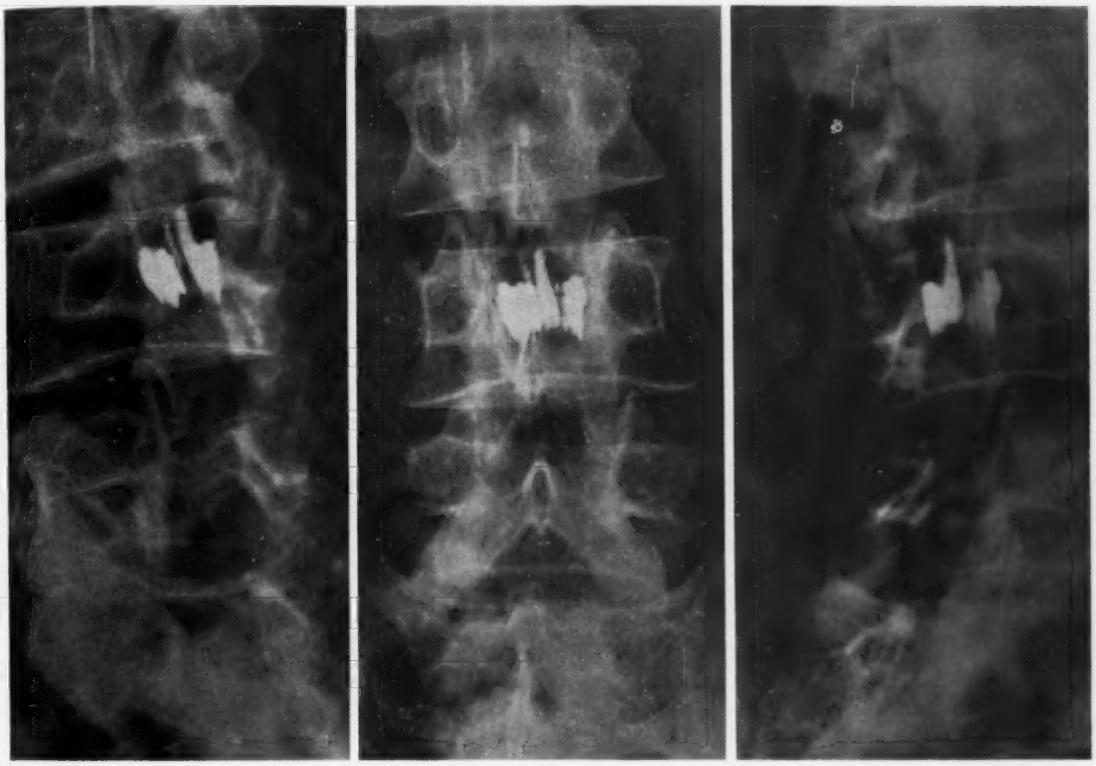

Fig. 25. Myelogram of a fifty-five year old man. One and one-half cc. of contrast medium injected into the cisterna magna was blocked opposite the lower half of L 4. Laminectomy showed the cause of obstruction to be a large midline disk protrusion at the fourth interspace.

Fig. 26. A fifty-five year old man had first developed pain in his right thigh while in bed six days before coming to the clinic. The pain had not been mitigated by two injections given by his doctor. For four days he had been unable to walk because of weakness of both ankles. A spinal puncture at L 4 showed evidence of an almost complete block. The protein level was 175 mg. per cent. One cc. of pantopaque injected in the cisterna magna was arrested opposite L 3. The striking feature of the block is the evidence of compression of the spinal sheath from behind. The third lumbar interspace is slightly narrowed, and a little subluxed. At laminectomy a large disk protrusion was found in the posterior part of the spinal canal, connected by a thin strand of nuclear material to the intervertebral disk.

was found not outside the dural sac but within it. To arrive at that location the nucleus pulposus must pass through not only the annulus fibrosus and the posterior longitudinal ligament, but also through the very tough dural sac. This unusual phenomenon probably could occur only in the event of firm adhesion of the dura to the longitudinal ligament, so that they are breached simultaneously. Figure 27 illustrates the situation encountered at operation. We have been able to find only 2 such

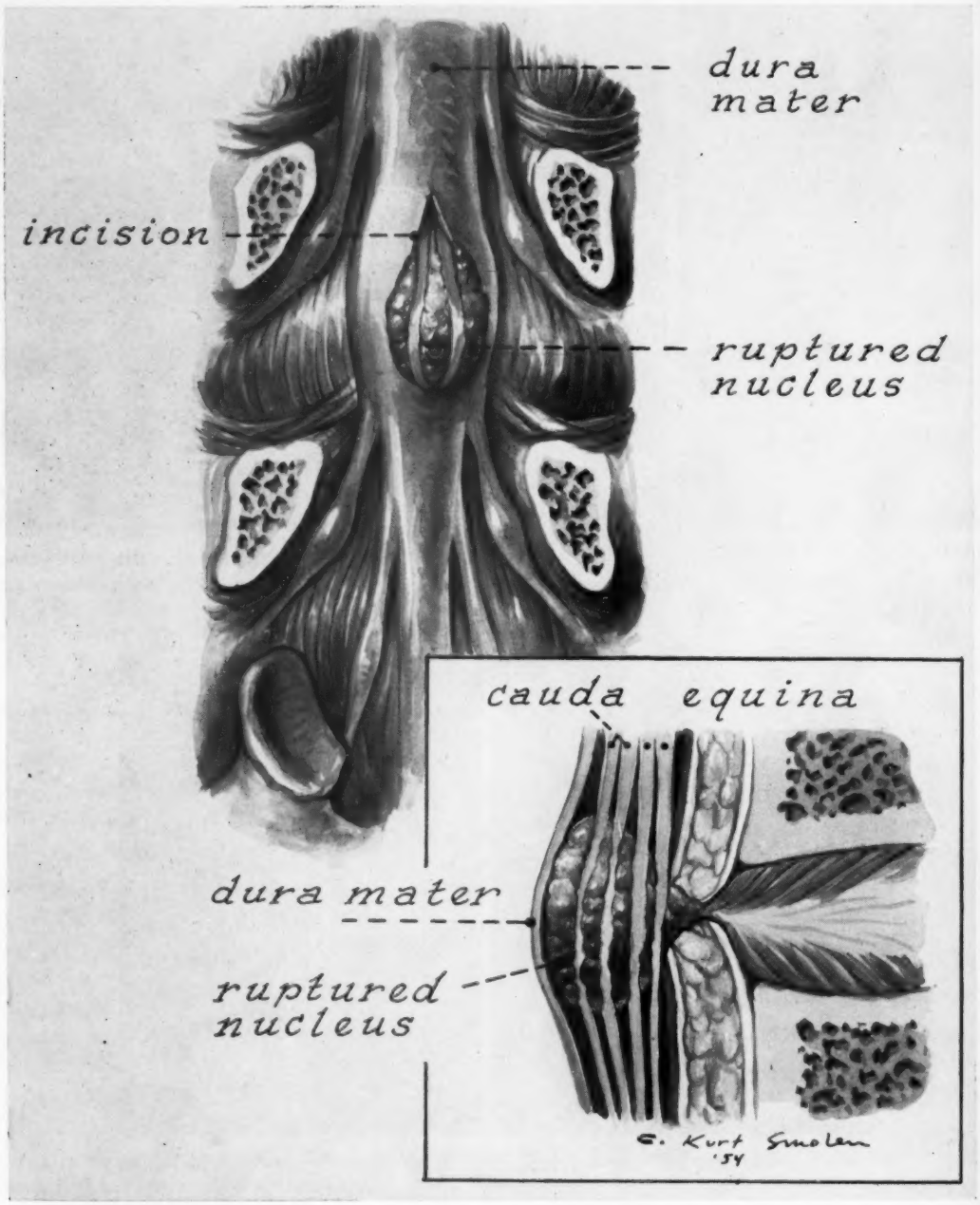

Fig. 27. Drawing showing the anatomic relationships encountered at laminectomy in the patients whose myelograms are reproduced in Figures 28 and 29. Inset illustrates, in sagittal section, the rupture of nucleus pulposus through annulus fibrosus, posterior longitudinal ligament, and anterior portion of the dura, with the mass displacing the nerves of the cauda equina.

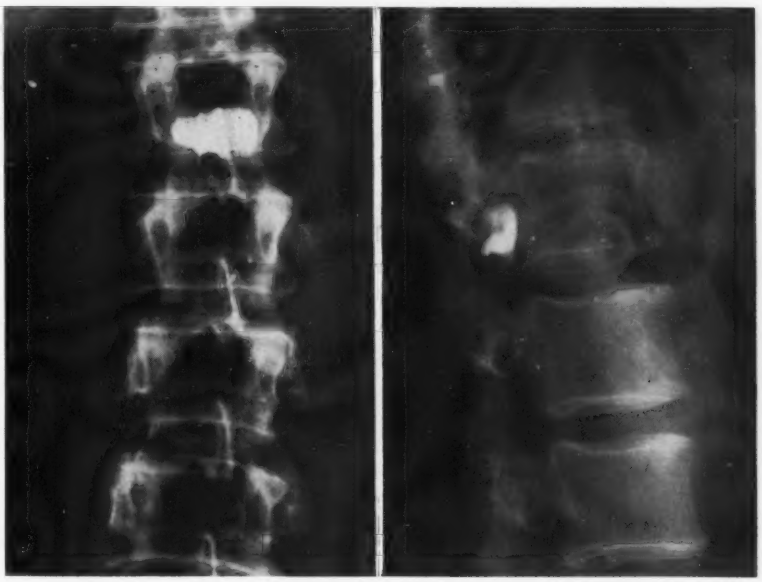

FIG. 28. Myelogram of a seventy-three year old man, showing a rounded defect producing obstruction at the first lumbar interspace. At laminectomy an intradural lesion was found accounting for the obstruction, but it proved to be a mass of extruded nucleus pulposus rather than a tumor.

cases previously reported in the literature.[16] The authors reported 1 as occurring at the fourth lumbar interspace, and the other as occurring at the lumbosacral interspace. They suggest that there may be more room for large disk fragments within the dural space than without, and that the presence of such intradural fragments may cause less neurologic disturbance than similar fragments in the extradural space.

One of the 2 patients with intradural disk protrusions in our series was a seventy-three year old man who had a history of intermittent backaches of fifteen years' duration. Six weeks before admission, the patient had suddenly developed severe pain in the leg; the day before the onset of pain he had shoveled snow. A day after onset the pain spread into both buttocks and down the right thigh. It was aggravated by coughing and sneezing. Slight mitigation was obtained by staying in bed.

A lumbar puncture was attempted at the first lumbar interspace but had to be abandoned because of excruciating pain in the leg. A tap was then accomplished at the lumbosacral space, which showed a complete block. The cerebrospinal fluid protein level was 600 mg. per cent. One cubic centimeter of pantopaque was instilled into the cisterna magna, and subsequent roentgenograms showed arrest of the medium above the first lumbar interspace, with a concave defect suggesting an intradural lesion (Fig. 28). The patient was operated upon, with the expectation of finding a tumor. However, neither a tumor nor a disk protrusion was encountered. A thickening was palpable within the dura, which, upon intradural exploration, the surgeon found was due to a large, firm, shaggy mass of glistening white material. Further inspection revealed a linear tear in the dura through which the material had apparently passed, and a sinus tract leading through the annulus fibrosus into the disk. Pathologic examination of the intradural mass proved it to be nucleus pulposus.

The other patient was a man, forty-eight years of age, who had first developed pain in the small of his back eight years previously. At that time his condition was treated with a Bennett brace, and he obtained relief from pain for a four-year period. Subsequently, the backaches returned, and eight months before admission he experienced

sudden pain down his leg to his foot. He was given a series of 12 injections of cortisone and felt improved, but five weeks before admission a pain of even greater severity developed. Since that time he had been completely incapacitated, and had been unable to lie in one position for more than ten minutes at a time.

Lumbar puncture disclosed a rise in pressure on jugular compression, but the fluid was xanthochromic. Although the specimen clotted, the cerebrospinal fluid protein level was reported as 1,340 mg. per cent. One cubic centimeter of pantopaque was introduced into the cisterna magna, and the films showed a complete obstruction at the first lumbar interspace, which was slightly narrowed (Fig. 29). At laminectomy a large mass of nucleus pulposus was found entangled among the nerves of the cauda equina. The entrance of the mass to the dural space apparently had been gained through a rent 1 cm. long which was found in the anterior surface of the dura. Pathologic examination of the mass confirmed the surgeon's impression that it was protruded disk material.

SUMMARY

Seventy-five myelograms in a consecutive series of 196 have shown complete block of the spinal canal, an incidence of 38.8 per cent. Intramedullary lesions as a cause of obstruction were almost insignificant in comparison with extramedullary lesions. According to the distribution of pantopaque, the lesions are classified as fragmentary or abrupt. Among the abrupt occlusions it is frequently possible to distinguish between extradural and intradural causes.

Neurofibromas have been the most common cause of obstruction in this series, with an incidence of 20 per cent. Most of these were extradural, but some were intradural. Spinal meningiomas were common, comprising 14.7 per cent of the total. These provided classic examples of intradural tumors. Twenty per cent of the obstructions were due to malignant tumors of various cell types, all of these being extradural.

Another 16 per cent of the spinal obstructions were proved to be due to ruptured intervertebral disks. The most striking examples were 2 cases in which large fragments of the

Fig. 29. Myelogram of a forty-eight year old man showing a somewhat funnel-shaped obstruction that indicated both intra- and extradural components of the ruptured nucleus pulposus that was causing the compression.

nucleus pulposus were extruded through a rent in the dura and were found free in the subarachnoid space, among the roots of the cauda equina. Both of the intradural protrusions occurred at the first lumbar interspace.

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MEASUREMENT OF THE CERVICAL SPINAL CORD IN PANTOPAQUE MYELOGRAPHY*

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IN PANTOPAQUE myelography of the cervical spinal canal the problem not infrequently confronts the radiologist to distinguish a normal cervical cord from an abnormally wide diseased cord. While it is often true that the enlargement is grossly obvious, it is equally possible that some difference of opinion may arise as to the significance of the findings in some cases.

Only one article could be found in the American literature of the past ten years which attempted to facilitate the diagnosis of cord enlargement by actual measurement of the cervical cord. Accurate measurements of the cervical cord at every vertebral level were reported by Lowman and Finkelstein[3] on a series of 80 unselected pneumoencephalograms. The measurements were made on the lateral projections with the exposure being made at 72 inches anode-film distance. These authors found a marked difference between the sagittal diameter of the normal cord (maximum average measurement = 1.0 cm.) and that of 2 cases of cervical cord disease (21.0 mm. and 15 mm. max.)

The purpose of this paper is to present the results of measurements of the transverse diameter of the cervical cord shadow in a series of 65 pantopaque myelograms, two of which demonstrated abnormal cervical cord enlargement. All of the patients were operated upon either as an exploratory procedure or, in most cases, for the removal of a ruptured cervical disk. Although the dura was not opened in most of these cases, it is probable that the surgeon would have recognized gross cord enlargement had it been present.

PROCEDURE

The films employed for the measurements were exposed during the fluoroscopic procedure in the course of myelography following the subarachnoid injection of 6–9 cc. of pantopaque. A rotating anode tube was used employing 80 kv. peak and 150 ma. The anode-to-spine and the spine-to-film distance, of course, varied to some extent in each case, but, in general, it is not felt that a significant variation in the measurements resulted. The average anode-to-spine dis-

FIG. 1. Normal cervical myelogram demonstrating method of measurement. Note importance of measuring "inner" shadow of true cord rather than entire central shadow which includes nerve roots.

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tance was 23 inches and the usual spine-to-film distance was 10 inches. It is, of course, obvious that the increased object-film distance necessitated by the procedure produced considerable distortion. However, it should be emphasized that no attempt was made here to obtain measurements of the actual cord width. The measurements presented in this paper were made in the hope of providing a guide in the interpretation of myelograms wherein some doubt arises as to the presence or absence of an enlarged cord shadow. Measurements were made at the level of the fourth and sixth cervical vertebrae insofar as possible but frequently the technique of filling and filming was such that satisfactory measurement of the cord could only be made at one of these levels. These levels were selected because usually the cord was most clearly visualized in this region and also because the normal cervical enlargement (intumescentia cervicalis) occurs at this level. Figure 1 demonstrates the points of measurement in a normal cervical myelogram.

RESULTS

Sixty-three of the patients showed either ruptured intervertebral disks or no pathology at operation. The average maximum width of the cervical cord in these cases was 1.4 cm. The measurements ranged from a minimum of 1.0 cm. to a maximum of 1.7 cm. No measurement above 1.7 cm. was recorded in this group of patients.

The remaining 2 patients suffered from intramedullary tumors of the cord, one an astrocytoma and the other an ependymoma. The maximum width in the former was 2.7 cm. and in the latter 2.2 cm. Figure 2 demonstrates the myelogram in the latter case.

CONCLUSION

It is obvious that the number of pathologically enlarged cervical cords is too small to be of much significance in this series. It is equally apparent that no attempt has been made to accurately measure the true width of the normal cord.

However, it is felt, from the study of 63 myelograms in patients without symptomatic or surgical evidence of cord disease, that a somewhat more accurate determination of what represents a normal or enlarged cord shadow can be made. Employing similar exposure factors and proper measurement of the cord shadow at its maximum width, one could certainly state that a measurement of 2.0 cm. or over is definitely abnormal and a measurement of 1.8 cm. or higher should be regarded with suspicion.

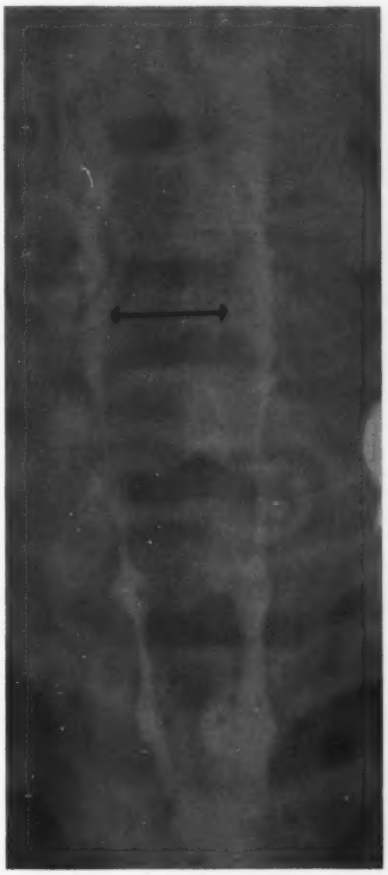

Fig. 2. Ependymoma of cervical cord. Note abnormal width of the cord shadow even at the narrowest point.

SUMMARY

1. Measurements have been made of the spinal cord shadow on 65 patients who underwent surgery following cervical myelography.

2. It is concluded that, with similar tech-

nique, a cord shadow measurement of 2.0 cm. or over is abnormal.

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THE IMPORTANCE OF MYELOGRAPHY IN SPINAL PATHOLOGY

ANALYTICAL STUDY OF 150 CASES

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THE scope of this paper is mainly to present our experience with myelography through a critical analysis of 150 cases in which this study was carried out at the New York Medical College, Flower and Fifth Avenue Hospitals during the period 1950–1953. It is also our intention to discuss and correlate our findings and statistics with the ones reported in literature. Furthermore, some significant facts that we have gathered during this study and which have been either minimized or neglected by other authors will be considered.

The chronologic development of myelography as a diagnostic means has undergone many laborious trials, painstaking investigations and criticisms. Myelography as has been shown by the many excellent papers on the subject, is recognized as an effective procedure in the discovery and localization of spinal tumors even though many have doubted its usefulness in the diagnosis of disk prolapse.

The study of the visualization and localization of lesions affecting the spinal cord or neighboring structures received some impetus since Dandy[17] postulated, in 1919, that the use of air injected into the subarachnoid space could be of value in detecting tumors of the spinal cord.

HISTORIC REVIEW

In 1921 Wideröe[71] described a case in which air was injected into the spinal subarachnoid space and in which he diagnosed a meningioma roentgenographically. This was the first case of contrast myelography published.

Sicard and Forestier[60] in 1922 introduced an opaque oily substance containing iodine as a contrast medium for the visualization of the spinal subarachnoid space. This opaque material appeared to offer good contrast, but, because of the possibility of its irritative effect, further investigation was necessary. The enthusiasm for this method diminished somewhat when Odin, Runström and Lindblom[46] reported cases of adhesive arachnoiditis and meningitis following the use of lipiodol. The disclosure of these cases led many clinicians in Europe to abandon this method. In America, however, the interest in lipiodol myelography continued unabated and the unusual investigations of Mixter,[43] Craig,[15] Camp,[13] Love[39] and many others established excellent myelographic diagnostic criteria. At the same time the surgical approach for lesions affecting the spinal cord was being explored and developed. During the period from 1928 to 1937, surgery was performed only in the presence of positive myelographic evidence. As experience in this field increased, herniations of the intervertebral disks were studied thoroughly and the findings correlated with the clinical aspects. This led some authors (Bradford and Spurling[9] and others) to affirm that physical examination yielded more reliable information than myelography. Dandy and others thought that the method leads to many diagnostic errors and went so far as to consider it of doubtful value. This controversy continued even after the introduction in 1944 by Ramsey, French and Strain[51] of a new opaque material, pantopaque, which proved to have many advantages over lipiodol since supposedly, it was more absorbable and less irritating. Soule, Gross and Irving[61] and others reported in 1945 on the accuracy of pantopaque myelography in the diagnosis of disk lesions. These favorable reports were immediately challenged by others, culminating in a critical article by Scoville

and associates[56] in 1948, in which the authors attempted to demonstrate that the errors in myelographic interpretation were so high that reliance on this method was to be questioned. Excellent articles re-evaluating pantopaque myelography have been published more recently and most agree on the significant diagnostic usefulness of the procedure. The articles of Maltby and Pendergrass[42] (1946), Camp[13] (1950) and Leader and Rassell[35] (1953) are especially noteworthy in this respect.

During the same time, in Europe, mainly through the influence of investigations carried out in the Scandinavian countries, a new contrast substance was tried which now has become the medium of choice in this part of the world. Its proprietary name is abrodil and it is chemically similar to the American preparation—skiodan. Arnell and Lindström[2] in 1931 reported the first case in which abrodil was employed. Subsequent reports came from Arnell[3] (1944) and Lindblom[37] (1946). In 1948[4] Arnell summarized the experiences with abrodil in a comprehensive monograph. This medium, according to him, offers high diagnostic accuracy and is advantageous because of its water solubility, nonirritant effect, optimum absorption and elimination and good opacification. The reluctance in accepting this contrast medium in America lies perhaps in the fact that the same Swedish authors have reported various complications following its injection. Thus Lindblow has observed not infrequently lumbosacral pain, spasm of thigh and leg muscles, shock and headache.

In an effort to find an ideal contrast medium, the lumbar injection of air was also tried. The visualization of lesions of the spinal column with air does not offer, however, the definite clearness yielded by opaque media and there is the additional disadvantage of a constant headache after the injection.

ANATOMIC CONSIDERATIONS

It is of importance to review some of the anatomy pertinent to the subject in question for a better understanding of the myelographic shadows. The spinal cord and cauda equina are surrounded by the meningeal tube which is formed by the dura and arachnoid membrane. Each of these two structures accompanies the emerging nerve roots by means of sheaths. The inner layer of the sheath is formed by the prolongation of the arachnoid usually extending as far as the dorsal ganglion; the outer layer is formed by the dura. The subarachnoid space follows each nerve root and at the termination of the arachnoid membrane, at the level of the dorsal ganglion, it forms the "root pouch." The anterior wall of the meningeal tube is in close contact with the posterior longitudinal ligament and the posterior borders of the intervertebral disks. It is interesting to note that at the level of the fifth lumbar disk, areolar tissue is interposed between the spinal meninges and the posterior longitudinal ligament. This explains the slight anterior separation of the opaque column seen at this level in the lateral view of normal myelograms. The subarachnoid space extends as far as the second sacral segment and in some individuals it terminates higher up at the level of the lumbosacral articulation.

PREPARATION OF THE PATIENT

In the preparation of patients for myelography several factors must be taken into consideration. First in order of importance is the full clinical evaluation of the case by the radiologist so that the appropriate technique can be employed to suit the particular situation. Furthermore, by knowing the clinical findings, the radiologist is better prepared to intelligently weigh the roentgenographic evidence and correlate it with the clinical picture. This can be accomplished only if there is close cooperation between the neurosurgical and radiological staffs. Another important factor in the preparation of the patient is a favorable psychologic approach by familiarizing him with the procedure and the possible physical hardships he might encounter. It is emphasized to him, that his full cooperation will shorten the examina-

tion and make it more tolerable. It is a good practice to inform the patient in advance of all the different steps that will be undertaken, thus avoiding tedious explanations during the procedure. In case the patient is emotional, premyelographic analgesia or even anesthesia may be employed. A mild sedative is administered routinely to all patients. In order to minimize extraneous abdominal shadows and improve visualization, a laxative is given the night prior the examination.

Scout roentgenograms of the spine are taken routinely in all cases, as valuable information may be obtained by an accurate analysis of these screening films.

Anomalies of the vertebral column may be detected. Spondylolisthesis and spondylolysis, which may present a syndrome simulating a disk protrusion, may be demonstrated. Other findings of importance are narrowing of the intervertebral disk spaces or evidence of Schmorl's nodules. The presence of hypertrophic spondyloarthrotic changes in the preliminary film has a particular value because, as will be discussed later, these degenerative changes, if marked, will produce myelographic defects indistinguishable from the lesions seen in disk prolapse, thereby limiting the differential diagnostic usefulness of myelography. Metastatic or tuberculous lesions occasionally give symptoms similar to the ones of nucleus pulposus herniation, and the scout films should help in recognizing these lesions.

TECHNIQUE

With the patient lying on one side on a roentgenoscopic tilt-table, a local infiltration with procaine hydrochloride 0.5 per cent is made at the level of the third lumbar interspace. Then, with the patient's knees flexed and drawn as close to the chest as possible, an 18 gauge needle is inserted at the third lumbar interspace using the necessary aseptic precautions. The technique we employ for lumbar myelography is similar to the one described by Kubick and Hampton,[33] and Soule and associates.[61] The third interspace is selected beause of the relative infrequency of disk protrusion at this level. In this way a myelographic artefact due to the needle will not complicate the differential diagnosis of intervertebral disk herniations which are predominant at lower levels. With the needle in the subarachnoid space, 3 cc. of pantopaque is injected. For cervical myelography we use 6 cc. In lumbar and lower thoracic myelographies in the majority of the cases we have employed 3 cc., and in some cases 6 cc. for control purposes. Camp[13] states that "if small non-obstructing lesions are to be found, an adequate amount of medium is necessary. Precise localization of the lesion is possible only if a quantity of 5 cc. or more of opaque material is used." We believe that this concept cannot be generally applied to all lesions. It is quite true and of importance in the detection of lesions in the cervical and upper thoracic regions, because a clear visualization of these areas can be accomplished only with sufficient quantity of the opaque material. We feel, however, that in lesions of the lower thoracic and lumbar regions 3 cc. of pantopaque is adequate, especially when myelography is performed to confirm positive clinical findings. The diagnostic accuracy of lumbar myelography has not been any higher in the cases in which we have used more than 3 cc. Begg and his associates[8] maintain that "if more than 3 cc. is used, the fluoroscopic shadow is too dense and the pool may be so deep that small projections cannot be seen through it." This, in our opinion, is particularly true in lumbar myelography. Therefore, we have not been enthusiastic about the method in which the entire column is filled with opaque material, as is being done in some institutions.

Multiple lesions may be discovered by a systematic study of each interspace and satisfactory visualization of the lower thoracic segments was obtained in most of the cases in which we used 3 cc. We usually start the fluoroscopic examination when the table is in the horizontal position and adjust the opaque material at the level of the third interspace. An anteroposterior

roentgenogram of this interspace is taken and the position of the center of the opaque column is recorded so that an adequate lateral exposure may be made subsequently. Then, by smooth progressive tilting of the table the descent of the opaque material is observed fluoroscopically at the level of each interspace distal to the point of injection. With the patient in the prone position, anteroposterior and lateral roentgenograms of each interspace are taken. The sacral sac is studied with the patient in a completely erect position. The table is then tilted back to the horizontal position and a rolled pillow is placed under the abdomen to arch the lumbar spine. With this device, we allow the easy ascent of the opaque material to the upper lumbar and lower thoracic spine by gradually tilting the table in the opposite direction. Routine

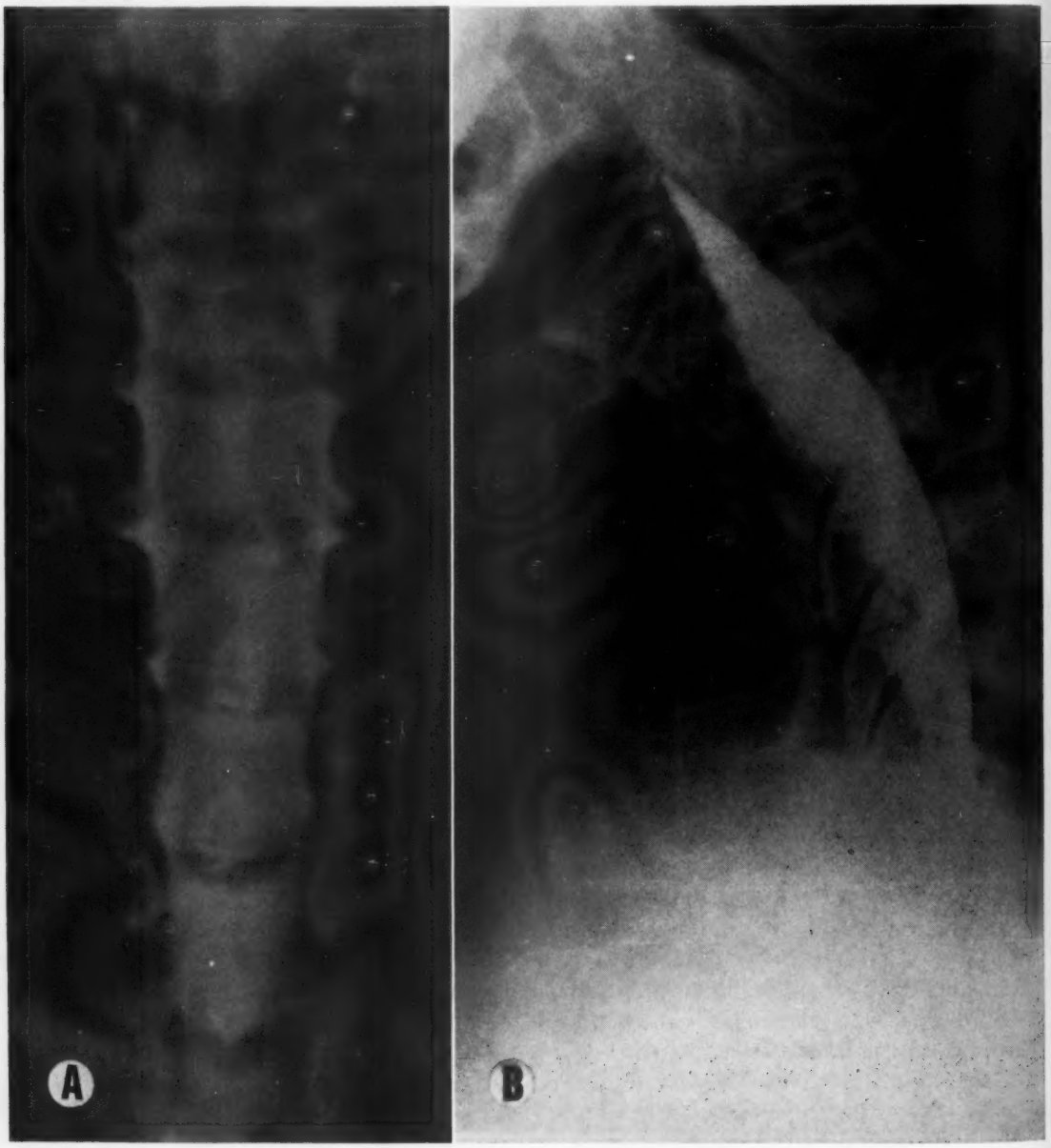

FIG. 1. (*A* and *B*) Anteroposterior and lateral views. Normal cervical myelogram.

roentgenograms of each interspace are taken. In cases in which a lesion is suspected fluoroscopically in any of the intervertebral spaces, control roentgenograms of these regions are taken by allowing the pantopaque to re-flow to the area in question.

For cervical myelography the patient is placed in the lateral recumbent position and the table again tilted to allow the opaque material to flow toward the cervical region. With the patient in this position, the opaque column ascends to the thoracic spine, bypassing without hindrance the dorsal curvature. At the time the pantopaque reaches the upper thoracic segments, the patient is quickly rotated in the prone position and the cervical segments are roentgenographed. During the entire examination, and especially in the prone position the head is kept hyperextended to prevent leakage of the pantopaque into the ventricular system. This can be accomplished by inserting a bulky pad between the patient's head and the surface of the table (Fig. 1 and 2). At completion of the study the table is tilted back to an almost complete vertical position to permit the descent of the opaque material to the lumbar region.

Complete removal of the contrast medium must be attempted because of the possibility of irritative effects resulting from the pantopaque left in the spinal canal. Peacher and Robertson[47] have reported a case of extensive arachnoiditis following the injection of pantopaque. One of our colleagues, Dr. Tarlov, has reported a case of meningitis disclosed at operation, due to the incomplete removal of pantopaque. We have noticed that by gentle rotation of the needle, with straining of the patient at the end of expiration and inspiration most of the material can be withdrawn without much difficulty. The removal of 3 cc. is much easier to accomplish than of larger quantities and the danger of prolonged fluoroscopy is minimized. This is, therefore, one of the factors that we must consider against the advocated use of larger quantities of opaque material.

Fig. 2. Anteroposterior view. Spill of the opaque material into the base of the skull.

Studies on the rate of absorption of the residual pantopaque show that an average of 3 cc. per year may be absorbed if the medium is spread over a large surface. When the medium is collected in the thecal sac, the rate of absorption is slower (0.5 to 1.0 cc. per year). Observations of Wyatt and Spurling,[74] however, indicate that the absorption should be complete at the end of several years.

MYELOGRAPHIC APPEARANCE

Before discussing the different myelographic defects encountered in our survey, we will briefly describe the outline of a normal myelogram and its variations.

The normal opaque column, as seen in the anteroposterior view with the patient in the prone position, is quite constantly symmetrical. It may be broad or narrow and is usually unrelated to the morphologic make-up or the sex of the patient. There is a wide range of variation in the length

FIG. 3. Anteroposterior view. Good visualization of the "root pouches."

and shape of the column. The "root pouches" may be visualized and may appear as small projections along the lateral border of the opaque column (Fig. 3). In the transvertebral view (lateral view with patient in the prone position) the opaque column assumes an elongated shape and presents slight indentations at the level of each intervertebral space due to normal slight extrusion of the nucleus pulposus and the ligaments covering it (Fig. 4). At the level of the fifth lumbar interspace the anterior indentation may be absent due to the increased epidural distance previously described as due to the presence of areolar tissue. We attribute a great importance to the transvertebral view because the demonstration of an indentation on the anterior surface of the opaque column greater than 2 mm. is, in our opinion, of definite pathologic significance (Fig. 5 *A* and *B*). In 9 cases of our series the anterior indentation seen in the transvertebral view, was the only demonstrable roentgenologic defect and the diagnosis of posterior disk herniation was proved to be correct at operation. The anteroposterior and lateral transvertebral views should always be used in order to obtain a reliable myelographic study. In a few occasions oblique views may offer additional information.

TYPES OF MYELOGRAPHIC DEFECTS IN SPINAL TUMORS

Spinal tumors are divided into two major groups. These are: I. *Intramedullary* tumors, arising within the substance of the cord, and II. *Extramedullary* tumors, arising outside the cord and including tumors of the cauda equina originating within the dura and among the nerve roots. The extramedullary tumors are further divided into (A) *intradural* and (B) *extradural* accord-

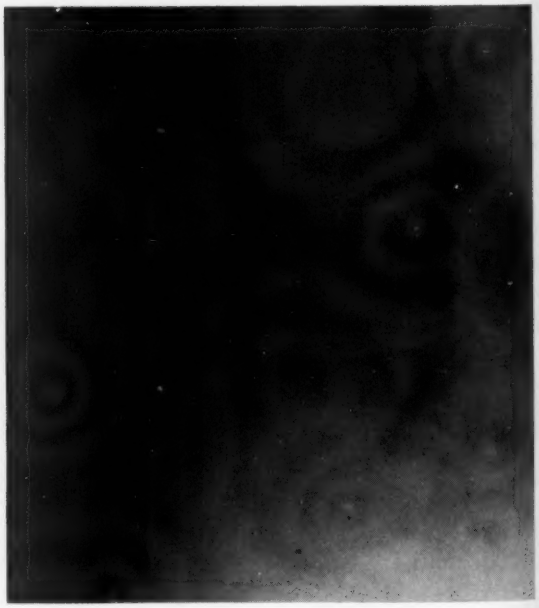

FIG. 4. Transvertebral view. Normal indentation on the anterior surface of opaque column (4th lumbar interspace).

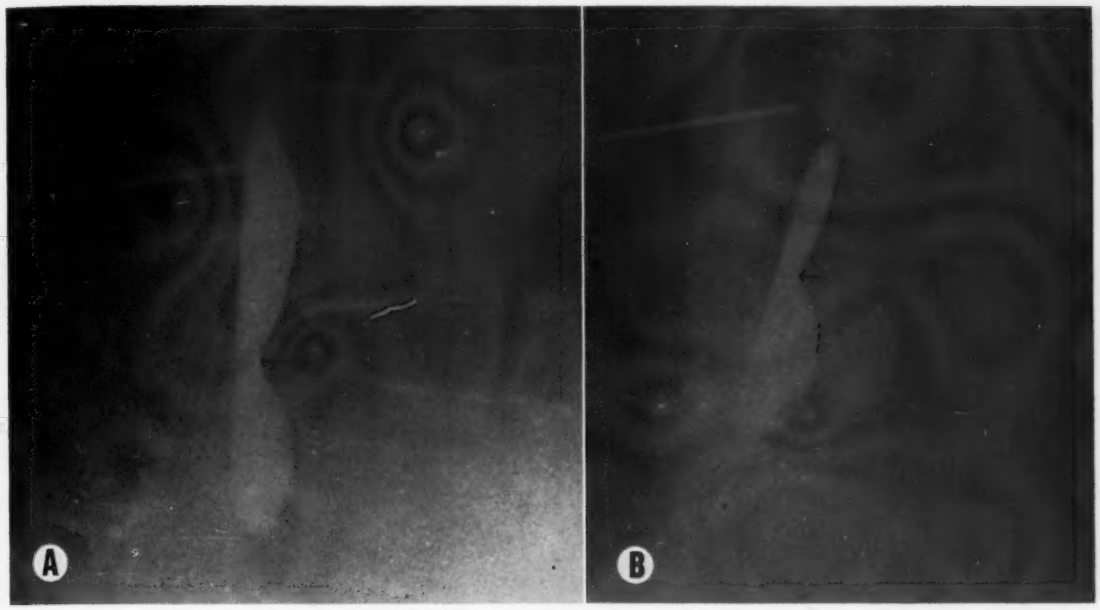

FIG. 5. (*A* and *B*) Transvertebral views. Indentation on the anterior surface of the opaque column due to a herniated disk (4th lumbar interspace). Notice that the indentation is greater than 2 mm.

ing to their location. The following is a detailed classification:

I. *Intramedullary*
- 1. hemangioma
- 2. glioma
  - a. astrocytoma (Grades I to IV)
  - b. ependymona (Grades I to IV)
  - c. oligodendroglioma (Grades I to IV)
  - d. neuro-astrocytoma (Grades I to IV)
  - e. medulloblastoma (Grades I to IV)

II. *Extramedullary*
- A. *intradural*
  - 1. fibrosarcoma
  - 2. neurofibroma (neuro-astrocytoma)
  - 3. perineural fibroma
  - 4. meningioma
  - 5. hemangioma
  - 6. lipoma
- B. *extradural*
  - 1. benign
    - a. simple cyst
    - b. chordoma
    - c. fibroma
    - d. osteoma
    - e. neurofibroma
    - f. lipoma
    - g. chondroma
    - h. giant cell tumor
    - i. hemangioma
  - 2. malignant
    - a. osteogenic sarcoma
    - b. fibrosarcoma
    - c. lymphosarcoma
    - d. hemangio-endothelioma
    - e. myeloma
  - 3. metastatic
    - a. breast carcinoma
    - b. thyroid carcinoma
    - c. kidney tumors
    - d. testicular tumors
    - e. nasopharnyngeal tumors
    - f. Ewing's tumor
    - g. Hodgkin's disease

Spinal tumors may give rise to different myelographic filling defects. Some of these defects may be fairly characteristic of a spinal tumor, others are not typical and may be produced also by other conditions. The following types are encountered:

1. *Fusiform Filling Defect with Absence of Clear Cut Margins.* It is characteristic of intramedullary tumors. This type of defect was seen in a case which proved to be an ependymoma of the lumbar spinal cord.

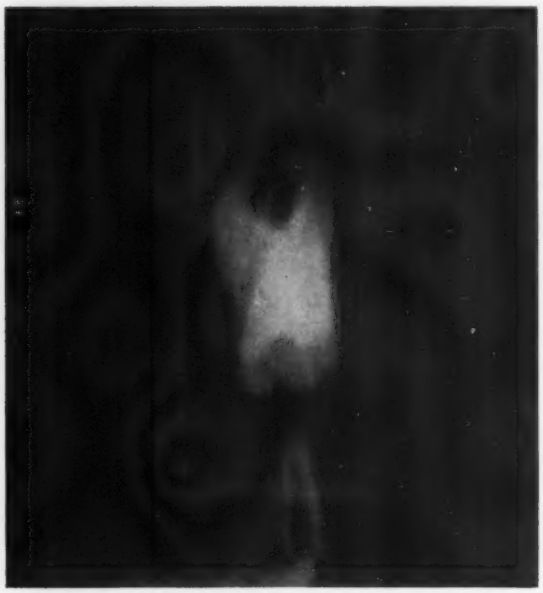

FIG. 6. Anteroposterior view. Concave defect and block produced by a telangiectatic meningioma at the level of the second lumbar vertebral segment.

FIG. 7. Anteroposterior view. Incomplete obstruction due to a lymphosarcoma (at level of the first and second dorsal segments).

2. *Sharply Defined Rounded Defect and Concave Defect* (*Fig. 6*). These are characteristic of intradural tumors.

3. *Pressure or Indentation Defect.* This is usually seen in extradural tumors causing an imprint on the opaque column.

4. *Incomplete or Complete Block of the Opaque Column* (*Fig. 7 and 8*). This may be produced by any of the spinal cord tumors, as well as by a large prolapsed disk. The differential diagnosis between these lesions in the presence of a block is difficult and often impossible. In 7 cases of our series, in which a complete obstruction was demonstrated, we were unable to make an accurate roentgenologic diagnosis.

TYPES OF MYELOGRAPHIC DEFECTS IN DISK PROLAPSE

The various types of defects occurring in herniation of the intervertebral disk have been extensively described in the literature. There is still some confusion at the present time as regards the nomenclature, and the

FIG. 8. Anteroposterior view. Complete block between the first and second dorsal segments caused by a meningioma.

importance of some of the myelographic lesions has either been overstressed or underemphasized. On the basis of our analysis we have subdivided the myelographic abnormalities observed in this prolapse as follows:

1. *Unilateral-filling Defect* (*Fig. 9*). This is the most frequent type of deformity. It has been described by Soule and associates[61] as a "lateral pressure defect." It is usually produced by a lateral herniation. It may be associated with incomplete obstruction, distortion of the nerve sheaths and irregularity of the column. We have observed this type in 38 per cent of the cases.

2. *Bilateral-hourglass Deformity* (*Fig. 10*). Close to 13 per cent of the cases presented this type of lesion, which consists of a bilateral or fusiform narrowing of the opaque column. Some authors believe that this defect is the result of a bilateral disk herniation. Begg and associates[8] consider it, instead, as being due to a midline protrusion that displaces the components of the spinal cord in two portions. A narrow passage is, therefore, formed between these portions, through which the opaque medium flows, creating the hourglass effect. This theory offers a logical anatomic explanation of the cause of this defect. We

FIG. 9. Anteroposterior view. Lateral pressure defect due to a lateral herniation of the disk.

FIG. 10. Anteroposterior view. Hourglass deformity at the 4th lumbar interspace due to disk protrusion.

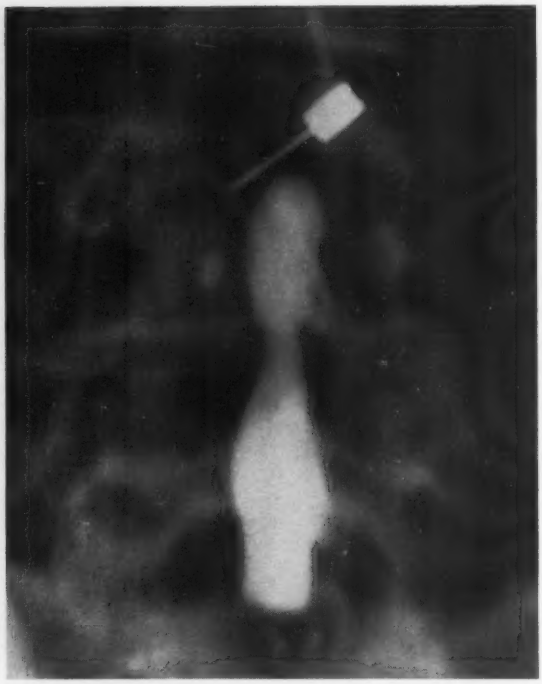

FIG. 11. Anteroposterior view. Waist-like narrowing due to a herniated disk.

have been able to prove at operation a definite central prolapse in some of the cases in which an hourglass deformity was demonstrated by the myelogram.

A slight narrowing (Fig. 11) of the opaque material at the level of the intervertebral disk is considered normal in the anteroposterior view, unless it is greater than 2 mm. on either side. It is a type of defect similar to the hourglass deformity, different from it only in degree. A moderate central protrusion is apt to produce this defect and was observed in 8 per cent of our cases.

3. *Block or Complete Obstruction.* We noted this effect, usually the result of a midline prolapse, in 8 per cent of the cases. One case showed a block in the upper thoracic region between the first and second dorsal segments. The opaque column presented an irregular upward concavity. At operation a large, necrotic midline protrusion was found. In another case, several years prior the admission to our hospital, a lumbar myelography was performed and reported negative. Due to the persistence of the clinical signs a second myelographic study was done. Scout films of the lumbar spine showed residual pantopaque in the cul-de-sac of the theca from the previous examination. The myelogram revealed a complete block of the opaque column between the fifth lumbar and the first sacral segment, and a gap of about 1 cm. was noted between the distal end of the opaque column and the residual pantopaque present in the meningeal cul-de-sac. At operation a large midline herniated disk was found and, according to the surgeon, it filled exactly the gap we had described.

4. *Anterior Indentation or Defect of Opaque Column Demonstrated in Lateral or Transvertebral View with Patient in Prone Position.* This type of myelographic defect has been frequently demonstrated in our series. As we have mentioned before, a slight indentation is normally expected on the anterior surface of the opaque column at the level of the intervertebral disks. However, if this indentation is greater than 2 mm. it assumes pathologic significance.

FIG. 12. Anteroposterior view. "Veil" defect due to a mid-line disk protrusion.

This defect alone or associated with lateral filling defects or an hourglass deformity was observed in 30 per cent of our cases. In 9 cases this was the only myelographic finding present. This lesion is second in order of frequency only to the unilateral filling defect and must be considered an important myelographic sign.

5. *"Veil" Defect (Fig. 12).* This type was described by Soule and associates[61] and consists of the visualization of an area of decreased density within the opaque material and is the result of a mild midline protrusion. It is rather uncommon. We observed it in 2 cases.

Fig. 13. Anteroposterior view. Nerve sleeve amputation produced by a mild lateral disk protrusion.

Fig. 14. Anteroposterior view. Traumatic avulsion of the mid-cervical roots. Notice the asymmetry of the root pouches and the irregularity of the opaque column. A pooling of pantopaque in pseudodiverticulum fashion may be noted on the right side.

6. *Nerve Sleeve Asymmetry or Amputation (Fig. 13).* Root defects have been a rare finding in our series. It is probably due to a lateral protrusion of a disk which impinges upon the nerve root without affecting the thecal column. In 2 of our cases the roentgenologic diagnosis of disk herniation was postulated on the basis of this finding, and lateral protrusions were confirmed at operation. Asymmetry of nerve sleeves may also be caused by traumatic lesions. Cervical myelograms, done in 3 cases with clinical suspicion of traumatic avulsion of some of the cervical nerve roots, revealed asymmetry of the root pouches and irregularity of the opaque column at those levels (Fig. 14). The clinical and myelographic findings were confirmed at operation. It should be noted, however, that the roentgenographic appearance might also be due to incomplete filling and should therefore be interpreted cautiously.

ANALYSIS OF THE CASES AND COMMENTS

With the assumption that a logical grouping of the cases might furnish a

better presentation of the material surveyed and analyzed by us, the cases will be divided into the following categories:

1. Cases in which, from the clinical picture, a diagnosis of either a spinal tumor or a degenerative disease of the spinal cord was considered. In 12 cases with positive myelographic findings, a spinal tumor was found at operation. The survey showed 2 intramedullary, 3 intradural, 3 extradural and 4 metastatic tumors.

2. Cases in which, from the clinical findings, the differential diagnosis was narrowed down to either degenerative disease of the spinal cord or spinal tumor, the latter being ruled out by a normal myelogram.

3. Cases with positive clinical findings of a prolapsed nucleus pulposus and positive myelographic defect proved at operation. In cases with positive findings myelography is performed to confirm the diagnosis and obtain an accurate localization of the lesion.

4. Cases with positive clinical findings and negative roentgenographic evidence in which no disk prolapse was disclosed at operation (9 per cent of our cases belong to this group).

5. Cases in which the clinical findings were not conclusive but myelographic evidence was positive for disk herniation.

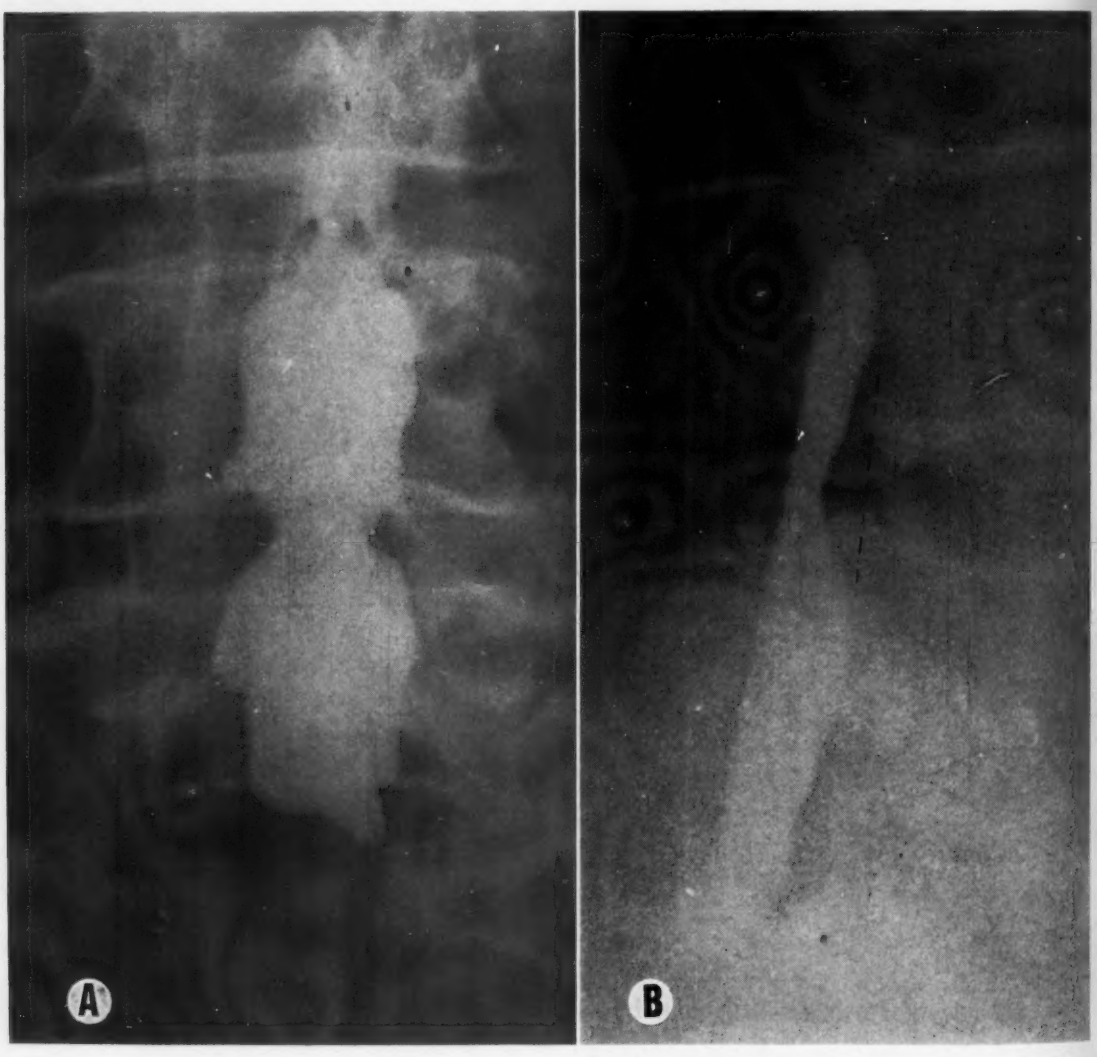

FIG. 15. (*A* and *B*) Anteroposterior and transvertebral views. Hourglass deformity and anterior indentation caused by marked hypertrophic spondyloarthrotic changes.

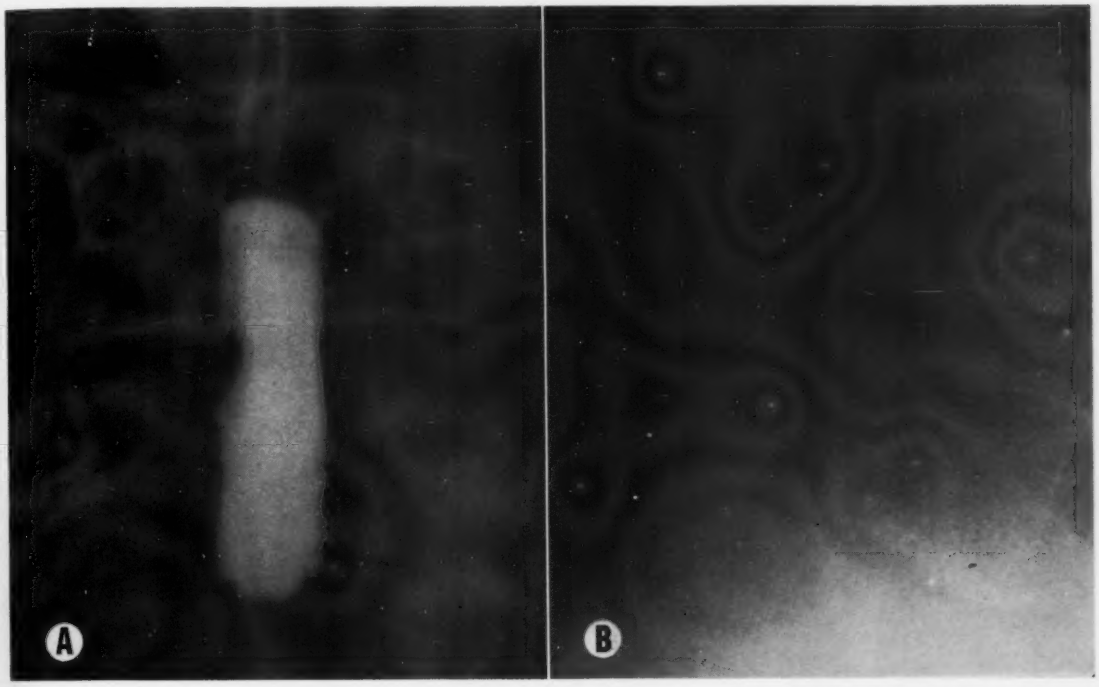

Fig. 16. (*A* and *B*) Anteroposterior and transvertebral views. Lateral pressure defect and anterior indentation caused by marked lipping changes.

These patients, 10 per cent of the series, had a prolapse proved on the operative table.

6. Cases in which the clinical findings were minimal or not contributory. Negative myelograms ruled out a disk protrusion and therefore operation was not justified.

7. Cases with positive clinical findings and negative myelograms which proved positive at operation (false negative, 11 per cent).

8. Cases with positive myelographic evidence and positive clinical findings found negative at operation (false positive, 4 per cent).

9. Cases in which myelographic filling defects were demonstrated, but marked hypertrophic spondyloarthrotic changes were also present (Fig. 15 and 16). We were unable to tell if the defects were caused by a prolapsed disk or by the arthrotic changes. In 3 of these patients the myelographic defects were produced by the proliferative spurs, as the exploratory laminectomy revealed. In 3 other cases with advanced osteoarthrosis and myelographic lesions, disks were detected at operation. We feel that, when confronted with such a problem, myelography becomes an unnecessary procedure because even the visualization of defects in the opaque profile cannot contribute much to the differential diagnosis. This does not apply, however, in cases which present minimal or moderate lipping changes.

The causes of errors in myelography are varied and we have had our share of them, although many could have been avoided by the proper evaulation of roentgenographic findings with the clinical picture. Myelographic errors may be classified as follows:

1. Hemorrhagic defects. These may be produced by the lumbar puncture needle and can be avoided by inserting the needle at a point distant to the suspected lesion. In lumbar myelography it is advisable to choose the third interspace as it is an unlikely site of ruptured disk.

2. Hypertrophic spondyloarthrotic changes. They may present myelographic defects simulating a protruded disk. If the

arthrosis is marked, as evidenced by scout films, the myelogram will offer little or no diagnostic help.

3. Inadequate scope of the examination. In cases in which a spinal tumor is suspected, all of the subarachnoid spaces should be carefully studied, as Camp has pointed out, to obviate the possibility of missing multiple tumors. When a herniation of the nucleus pulposus is suspected in the lower portion of the spine, the other intervertebral spaces of the lower thoracic and lumbar regions should also be examined. The radiologist may easily demonstrate a lesion at one level but may fail to complete the investigation of other interspaces thereby missing multiple herniations.

4. Improper injection of the opaque medium instilled by the inexperienced may cause leakage into the extradural spaces with formation of misleading pseudodefects. This error may be easily avoided if the lumbar puncture is performed by skilled surgeons.

5. Postoperative adhesions. A previous laminectomy may produce defects of several types or even a block in the myelogram. In the interpretation of these cases the differentiation between a recurrent herniated disk and postoperative adhesions is impossible.

6. Varices. Enlarged veins accompanying the nerve roots extradurally may give rise to pseudodefects simulating protruded disks. This type of error although difficult to prevent must always be kept in mind.

7. Defects due to previous lumbar puncture. Repeated attempts to introduce the needle may result in the rupture of one of the vessels in the subarachnoid space with bleeding and the formation of an organized hematoma and fibrosis, thus, yielding pseudodefects.

8. High termination of the thecal sac. The intervertebral disk spaces below the termination will not be visualized and a herniation at this level will be missed.

9. Deformities of the spinal column, anatomic variations (transitional vertebrae, hypertrophy of ligamentum flavum).

10. Concealed prolapses. Disks protruding too far laterally may be demonstrated by deformities of the root pouches; however, in most instances, they do not impinge on the opaque column and will not be seen.

11. Improper amount of contrast medium (less than 3 cc. or so much as to overshadow the lesion).

12. Non-cooperation of the patient also may be a source of error.

Some of these errors with improvement in our methods might be curtailed and the over-all accuracy increased.

The statistical analysis of our series points to a very high over-all percentage in which myelography was a decisive factor in correctly influencing diagnosis and treatment (88 per cent). The over-all percentage of proved accuracy in disk lesions was 85 per cent. These figures are approximately similar to those of Maltby and Pendergrass,[42] and Leader and Rassell.[35] The over-all percentage of errors was 15 per cent and definitely smaller than that reported by Scoville and associates[56] of 33 per cent. Although our false positive and false negative figures coincided more or less with theirs, we are not in accord with the statement made by Scoville and his group and repeated by others that the clinical evidence of ruptured disk is more important than the myelographic evidence. In 9 per cent of our series with definite positive clinical findings of disk prolapse that were operated on in spite of negative myelograms, no disks were disclosed after careful exploration. These cases shall be classified as "false positive clinical findings." Furthermore, in about 10 per cent of our patients in which clinical findings were not conclusive, positive myelograms suggested the presence of a prolapsed disk and the operative findings corroborated the roentgenologic impression. In these cases the clinical picture was not clear cut yet a herniated disk was presented and should be listed as "false negative clinical findings." Without aiming to belittle the

value of the clinical findings, it appears, nevertheless, that the interpretation of these findings is sometimes misleading, and that therefore it would be unwise to lean heavily on the clinical examinations alone when other helpful and more accurate procedures are available.

All the factors considered so far in the study of abnormality of the spine permit us to conclude that myelography should be a standard and routine method in all cases of suspected lesions of the spinal cord and its canal.

SUMMARY

1. A satisfactory method of positioning the patient for cervical myelography has been described.

2. Three cubic centimeters of pantopaque is a sufficient quantity for lumbar myelography. For cervical myelography at least 6 cc. should be used while larger amounts (9 to 12 cc.) are necessary for thoracic myelography.

3. Among the myelographic defects, the indentation on the anterior surface of the opaque column, as seen in the lateral transvertebral view, assumes particular importance and any indentation greater than 2 mm. should be considered pathologic.

4. Myelography should be done in every case in which a lesion of the spinal canal is suspected in order to facilitate the surgical exploration by establishing the exact level and type of lesion.

5. When the clinical evidence is controversial, such as in the differential diagnosis between degenerative diseases of the spinal cord and spinal tumors, myelography is a decisive diagnostic factor.

6. Myelographic findings in our series yielded an 88 per cent over-all accuracy in the diagnosis of all cases (over-all proved accuracy in disk lesions was of 85 per cent).

7. "False positive clinical findings" were present in 9 per cent of the cases and "false negative clinical findings" were seen in 10 per cent of the cases.

8. Clinical findings alone should not be considered as indication for surgery. Instead, all possible evidence should be evaluated to arrive at a proper diagnosis. In the presence of strong positive clinical findings a negative myelogram may be considered a "false negative."

9. In the presence of minimal clinical findings with negative myelograms, a watchful period of conservative therapy is advisable.

10. Since marked hypertrophic spondyloarthrotic changes cause defects similar to those of disk prolapse, the value of myelography in these cases must be questioned.

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THE ROENTGEN DIAGNOSIS OF HERNIATED DISK WITH PARTICULAR REFERENCE TO DISKOGRAPHY (NUCLEOGRAPHY)

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LOW back pain represents one of the most common yet most difficult problems encountered in the practice of medicine. The entire subject has been placed on a more rational basis since the clinical syndrome of herniated disk in the lumbar region was described by Mixter and Barr.[37]

Significant contributions have been made in the roentgenologic field to aid the diagnosis of disk pathology which represents the basis for the present communication. Initially, this includes a careful study of roentgenograms of the lumbar spine. These data have been most satisfactorily summarized recently by Begg and Falconer.[2] The following roentgen signs have been described as of localizing value in lumbar disk protrusion: (a) narrowing of the intervertebral space; (b) hypertrophic spondylitis; (c) localized scoliosis; and (d) relative displacement of a vertebral body. The signs of no localizing value are: (a) spinal deformity; (b) Schmorl's nodes; (c) anterior intraspongy nuclear herniation; and (d) hypertrophy of the disk.

Other incidental conditions described with lumbar disk protrusion which may be helpful in localizing the level of the lesion but which are not directly related to disk herniation include: (a) congenital defects: sacralization, spina bifida occulta, defect in the pars articularis of the neural arch, lateral wedging of the fifth lumbar vertebra, etc., and (b) acquired defects: arthritis of the lumbosacral and sacroiliac joints, articular facets. It is important to rule out nerve root compression in the intervertebral foramen by osteoarthritic changes as discussed by Hadley.[24]

MYELOGRAPHY

The introduction of radiopaque substances such as pantopaque and abrodil into the spinal canal has served as an additional impetus and great aid in the more accurate localization of these lesions. The importance of careful myelography has been stressed by Camp,[7] Boult, Kiernan and Childe,[4] Maltby and Pendergrass,[36] Haggart and Grannis,[25] Peacher and Robertson[38] and others. The full column technique also has particular merit especially in lesions of the lower lumbar disks as demonstrated by Bell, Wunderlick, Fett and Pool,[3] Malis, Newman and Wolf,[35] Fricker,[20] and Brierre and Colclough.[5]

The amount of pantopaque used to explore the spinal canal averages 6 cc. but the actual quantity will vary with the investigator (up to 24 or more cc.). More contrast medium (6–24 cc.) is required in the erect full column technique as described by Malis, Newman and Wolf,[35] Fricker,[20] and Brierre and Colclough.[5] Fricker[20] compared his results with both procedures. The diskogram was felt to be of additional confirmatory value when a bulging annulus was observed, as well as, in the demonstration of the amount of actual disk degeneration present. The other advantages of diskography will be discussed presently.

Indications for myelography are: differentiation of single and multiple disks; diagnosis of other pathologic lesions such as tumors, arachnoiditis, etc.; study of the spinal fluid chemistry and determination of the presence or absence of block; determination of the cause of postoperative symptoms; and detection of the possible position of tumor, intradural or extradural.

The advantages are that myelography: allows visualization of the entire spinal canal; is of value for differential diagnosis in tumors, disks, etc.; permits early recognition of the lesion obviating spinal

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cord compression; enables localization of lesion in disk pathology should surgery be necessary, thereby minimizing operative exposure; allows, occasionally, differentiation of tumor type, *e.g.*, angioma; is of medicolegal value; is easier to remove in contrast to lipiodol (some absorbable media are now available, *e.g.*, abrodil); is absorbed to some extent and is less irritating than lipiodol even though both are iodized oils; and will identify the majority of the acute cases with rupture of nuclear material in the spinal canal.

False negative results may also be observed. These may be caused by (1) anatomic variations: (a) high cul-de-sac, and (b) narrow spinal canal which will obviate demonstration of laterally and some posteriorly displaced disks, particularly at L-5. However, this can also occur at L-4 (Fig. 1); (2) extra-arachnoid injection; (3) insufficient number of films taken, *e.g.*, when oblique and lateral films are omitted; and (4) injection of inadequate amounts of contast material for satisfactory visualization.

False positive data include the following considerations: anatomic variation in the nerve sheaths; bony abnormalities: hypertrophic ridges, skeletal deformity; needle defects producing deformity of the arachnoid, bleeding, etc.; presence of other pathology: arachnoiditis, tumor, varices, hypertrophy of the ligamentum flavum, paradural scar, extra-arachnoid spinal fluid extravasation if myelography is done too early following spinal tap; misinterpretation of the anatomic level; and incomplete filling of the nerve sheaths emphasizing the need of sufficient amounts of pantopaque (6 cc. or more), full column technique, etc.

Cases falling within this category have been described by several investigators. For example, Scoville and co-workers[43] confirmed only 131 disk lesions following 196 positive myelograms. Ford and Key[18] reported 72.3 per cent success in 253 cases. Trowbridge and French[45] described 14 myelographic defects in the lumbar region without back symptoms in a series of 25

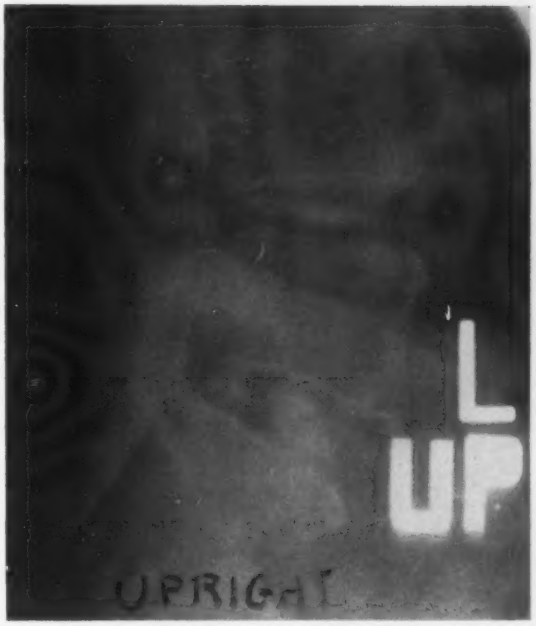

FIG. 1. Combined myelogram and diskogram. Myelogram negative. Note width of extradural space where false negative result may occur. This is demonstrated on subsequent diskogram revealing a lesion at L-4.

cervical myelograms. These results are less significant in that they are not verified and might well represent asymptomatic problems.

The disadvantages of myelography are as follows: introduction of a foreign material; rare cases of chemical arachnoiditis; psychic factors: lumbar puncture, residual contrast medium, medicolegal implications; disk protrusion may be present with normal myelography; slow absorption rate if incompletely removed (1 cc./year); (abrodil will answer some of these objections in that it is absorbable but it is only satisfactory in the lumbar canal, requires spinal anesthesia, produces a more severe immediate reaction, and is more time consuming); atypical defects may be difficult to diagnose such as in case of previous myelography with inadequate absorption (see false positive data); presence of a block may obviate penetration of the subarachnoid space: tumor, arachnoiditis, etc.; and there may be occasional tendency towards globule formation leading to difficulties in interpretation.

FIG. 2. Myelogram. Prone lateral film demonstrating protrusion at L-4.

FIG. 3. Diskogram. Lesion at L-4 corroborating previous myelogram (Fig. 2).

FIG. 4. Myelogram. Prone lateral film with suggested defect at L-4.

FIG. 5. Negative diskogram indicating that the defect in Figure 4 was a false positive.

DISKOGRAPHY

The study of diskography was initiated by Lindblom,[28,29,32,33,34] Lindblom and Rexed,[30] and Lindblom and Hustqvist.[31] The procedure, however, has not gained wide acceptance in this country. Additional data outlining variations in technique, diagnostic interpretation and results have been published by Gleason,[23] Smith, *et al.*,[44] Wise, *et al.*,[47,48] Erlacher,[15,16,17] Walk,[46] Gardner, *et al.*,[22] Cloward,[8] Cloward and Buzaid,[9] Dupuis, *et al.*,[14] Romanus and Yden,[41] Friedman and Goldner,[21] Zaaijer,[51] Buffard and Ecoiffier,[6] DeFilippis, *et al.*,[11] de Seze and Levernieux,[13] and Witt.[49]

Indications for diskography are: negative myelography; diagnosis of atypical back and sciatic syndromes; localization of site of lesion; differentiation of multiple disk protrusions; limitation of surgical exposure; determination of cause of postoperative symptoms: recurrence, etc.; medicolegal; clarification of suggested myelographic defects (Fig. 2, 3, 4, and 5); delineation of the nature of an obstructing lesion which may be due to disk pathology, arachnoiditis, etc., although caution need be exercised in this respect as noted above (Fig. 6 and 7); visualization of the intervertebral disk under actual stress: flexion, extension, upright films, etc. (Fig. 9, 10 and 11); diagnosis of intrinsic disk pathology, *e.g.*, degeneration with potential rupture, type of herniation (lateral, posterior, anterior etc.).

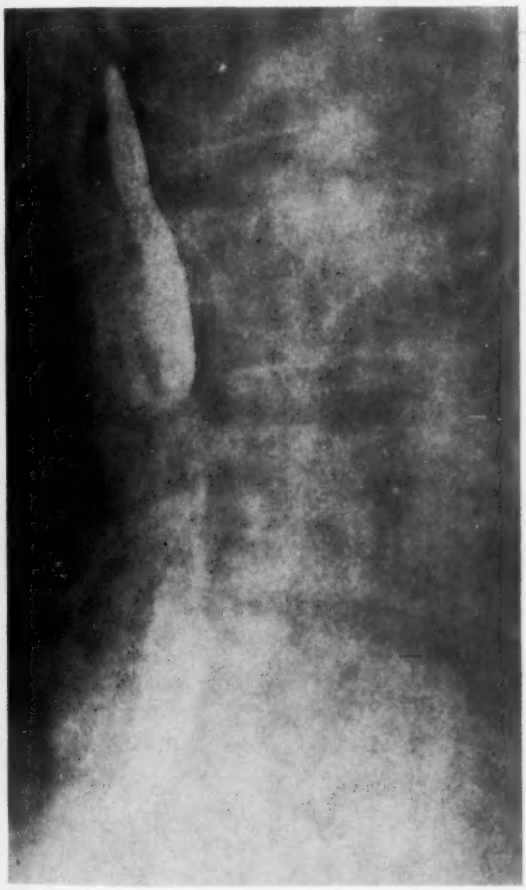

FIG. 6. Myelogram. Prone lateral projection revealing a partially obstructing lesion at L-4, felt to be due either to a chronic arachnoiditis or recurrent disk protrusion.

FIG. 7. Diskogram. No disk pathology at L-4 (other than a narrow interspace) signifying that the deformity present in Figure 6 was most likely due to chronic arachnoiditis.

Fig. 8. Degenerative disk disease at L-3 with anterior herniation. Note epidural contrast medium at L-3 and L-4, representing leakage of diodrast along the needle pathway after removal rather than disk protrusion. Rapid absorption of contrast material at L-5 obviated satisfactory visualization at this level.

Some investigators prefer this procedure to myelography when localized disk pathology is suspected. However, as Cloward and Buzaid[9] have pointed out, it should not be performed when actual disk rupture has occurred into the spinal canal for several reasons. There is greater risk of local nerve root trauma during disk penetration due to anatomic distortion of the caudal structures consequent to herniation. Also more severe local symptoms may result from extradural extravasation of the contrast medium if there is an opening through the annulus fibrosus. Actually, the majority of such cases can be diagnosed by the history, progress, clinical findings and myelography. These authors do, however, recommend diskography in cases of long standing low back pain on the basis of possible underlying degenerative disk disease with or without mild protrusion, non-localizable on the myelogram.

Friberg[19] also feels that low back pain and sciatica are secondary to degenerative changes in and around the lower lumbar disks. This process is ultimately followed by arthritis in the intervertebral joints. Protrusion of the disk in such cases is uncommon. Conservative therapy is advised as degenerated disks have a tendency towards healing. Surgery with lumbosacral fusion is reserved for the recalcitrant cases, with preliminary myelography and /or diskography.

The following are advantages of diskography: (1) complete absorbability of diodrast; (2) removal of contrast medium

Fig. 9. Extension film showing degenerative disk disease at L-3, L-4 and L-5 with protrusion, anteriorly and posteriorly at L-3, and posteriorly at L-4. Localized osteophytes are present at L-3, anteriorly.

unnecessary; (3) low morbidity. Hospitalization is not needed but is the usual practice; (4) secondary disk rupture or degeneration has not been seen although Gardner, *et al.*[22] have reported one case of septic necrosis; (5) minimal percentage of error; (6) specific for disk diagnosis; (7) potential irritating chemical not used in the subarachnoid space; (8) may establish the presence of disk disease without evidence of herniation, radiculitis or neurologic signs (Cloward and Buzaid[9]); (9) provides information as to the actual anatomic status of the disk rather than its effect on nerve root compression (as in myelography): herniation, degeneration; (10) various types of protrusion may be identified: anterior, lateral, posterior, vertebral, etc. (11) reduces myelographic error; (12) estimation of spinal fluid pressure, chemistry, presence of block, etc., can be accomplished prior to penetration of the intervertebral disk if desired; (13) a paradural approach may be employed to avoid dural entry for the determination of disk pathology in the presence of a known arachnoiditis; (14) will help clarify the nature of an obstructing lesion: extradural disk fragments, arachnoiditis, etc., when a previous myelogram has been performed; (15) may confirm presence of disk rupture following a previous equivocal myelogram.

Fig. 11. Upright position (same patient as in Figures 9 and 10) with further herniation at L-3.

Fig. 10. Flexion film of the same case as in Figure 9 with slightly greater protrusion at L-3.

The limitations for diskography are that: (1) it is usually limited to the diagnosis of the lower three lumbar disks. Examination of the upper lumbar, dorsal and cervical disks is possible (see Tech-

nique) but less practical; (2) it is no value other than in lesions of the intervertebral disk; (3) false negative results may occur if the injection is not made in the center of this disk; (4) false positive results may be possible due to leakage of the contrast material along the pathway of the needle after removal (Fig. 8); (5) considerable experience is necessary for interpretation of films; (6) multiple lumbar punctures are required; (7) relationship of disk to nerve root is not clearly defined; (8) it is more time consuming than myelography. This concerns the fluoroscopic guidance and films on the part of the radiologist. Also from the examiner's standpoint, the needle must be centered correctly, *e.g.*, in 12 per cent of the cases of Gardner, *et al.*[22] the annulus fibrosus had to be punctured more than once for satisfactory positioning; (9) more technical skill is required than for myelography. In this respect 17 unsatisfactory disk injections from a total of 186 attempts in 89 patients were reported by Gardner and his associates.[22] Thirteen were at L-5 level, probably due to narrowing of the intervertebral space, obliquity or deformity of the interspace making disk penetration difficult. Other failures were due to inability to inject the contrast medium or rapid dispersion of the opaque medium; (10) it is inadvisable when actual disk rupture is suspected with extradural fragments for the reasons pointed out previously by Cloward and Buzaid,[9] (see Indications); (11) occasionally rapid absorption or dissemination of the contrast medium obviates satisfactory visualization for diagnosis on subsequent films (Fig. 8, L-5).

TECHNIQUE

The majority of investigators have preferred the more simple transdural approach in the midline. A paradural oblique disk puncture has been suggested by Erlacher[15,17] and Zaaijer[51] in order to avoid penetration of the dural sac. A posterolateral technique (45–60° lateral) is necessary above the third lumbar disk.[32] This method allows the needle to pass anterior to the intervertebral foramen thus avoiding dural entry. Lindblom[32] has also described a technique of cervical disk examination utilizing an anterolateral approach. Perl[39] injected the lumbar and dorsal disks anteriorly during abdominal and thoracic operative procedures for unrelated pathology.

The fourth and fifth lumbar disks are usually injected in those cases with negative myelography or the procedure may be limited to those disks with suspicious pathology following pantopaque evaluation. Occasionally three or four disks may be infiltrated, particularly with unsatisfactory myelography or when the latter procedure has been omitted.

Lindblom[29] originally used a combination of an 18 and 22 gauge lumbar puncture needle, the actual disk puncture being made with the smaller needle. Gardner, *et al.*[22] later suggested 21 and 26 gauge needles which are now generally preferred. Our technique has been greatly simplified by the use of a 20–22 gauge lumbar puncture needle, $3\frac{1}{2}$–4 inches long without resorting to the previous double needle method. We have tried the various postures recommended by other investigators, but prefer the lateral recumbent position as for ordinary spinal tap. The needle is usually placed with its point in the center of the disk although Gardner, *et al.*[22] prefer to inject the contrast material into the posterior portion of the annulus fibrosus.

The majority of previous authors have taken roentgenograms in frontal, lateral and oblique projections with satisfactory results. We have not felt that the oblique films added much to the diagnosis, other than in occasional lateral protrusions which are also visualized on frontal films (Fig. 12). Greater benefit has been derived from extension and flexion films together with an exposure in the erect position (Fig. 9, 10 and 11). This allows a study of the disk in various simulated conditions of normal stress and strain. The flexion and erect positions have been of particular value to

demonstrate the greatest degree of protrusion. Although one would ordinarily anticipate the disk to be more prominent in flexion than extension, the reverse situation has occasionally been noted. Ordinarily the greatest herniation has been observed in the erect position. Lateral bending films have also been used without adding a great deal to the picture. We have observed few anterior, lateral or vertebral body herniations, the posterior herniation being the type most commonly noted.

A normal disk will generally take 0.5–1 cc. of diodrast, with herniated and degenerated disks absorbing 3–5 cc. In fact, large quantities of contrast medium could be injected in the presence of a rupture of the annulus fibrosus, the fluid escaping into the epidural canal. This, of course, is not the recommended procedure as previously described. Furthermore, the presence of epidural contrast substance alone does not imply the presence of a torn annulus fibrosus with disk fragments in the spinal canal (Fig. 8) as will be discussed in the next section (Roentgenologic Appearance, 4. Herniation).

Absorption of diodrast from the intervertebral disk varies considerably as emphasized by Cloward and Buzaid.[9] It may disappear so quickly that no shadow will present on roentgenograms taken shortly thereafter. These authors further state that the contrast medium cannot be visualized in these cases after twenty minutes and that the absorption is more rapid in normal disks. Our expereince has been comparable to that of Gardner, Wise, Hughes, O'Connell and Weiford[22] in that the contrast material is more apt to disappear in a short period of time when disorganized. Also, shadows may remain apparent in the films for twenty-four hours or longer particularly in negative examinations. Lindblom[33] also comments upon the fact that diodrast quickly diffuses into the disk tissue and disappears within twenty-four hours (Fig. 8, L-5 disk).

We plan to compare our myelographic

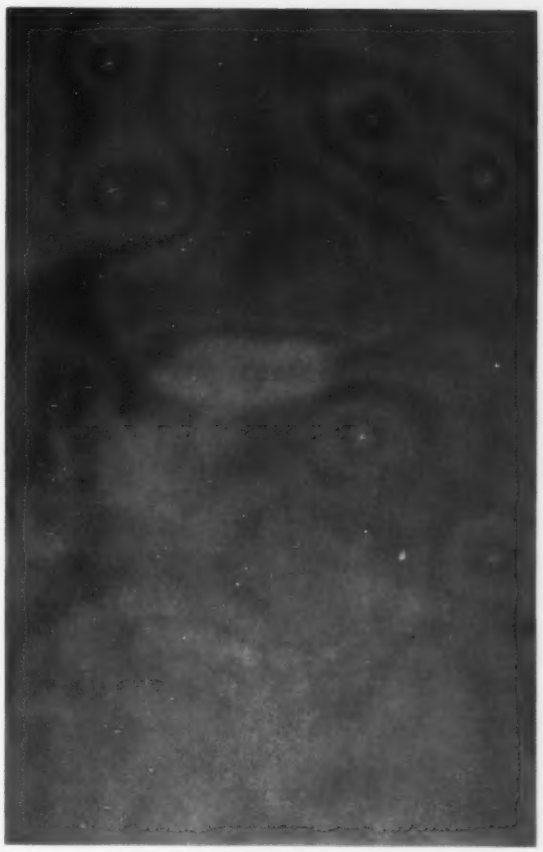

Fig. 13. Lateral view showing normal bilocular configuration of the disks at L-4 and L-5.

Fig. 12. Oblique view with extrusion of disk material laterally at L-4.

Fig. 14. Frontal film showing normal bilocular appearance of the disk at L-4 with disk degeneration at L-5 in a postoperative case with recurrent pain.

and diskographic data in a later report as well as to correlate the diskographic findings in those cases in which surgery has been performed.

ROENTGENOLOGIC APPEARANCE

1. *Normal.* A central bilocular or ovoid appearance of the nucleus pulposus is visualized (Fig. 13 and 14). Injection of 0.5–1 cc. contrast medium is usually possible, often with great resistance. Low back pain may result but usually not radiculitis.

2. *Degeneration.* The films usually present a diffuse disorganized appearance with varying degrees of opacity and extension (Fig. 15, L-4). Usually 3–5 cc. of contrast medium may be injected with ease. Low back pain alone may be noted. This stage may well be a precursor to actual disk protrusion. Walk,[46] Cloward and Buzaid,[9] and others find that the plain roentgenograms in these cases may be abnormal with narrowing of the intervertebral space, hypertrophic spondylitis, etc. Myelograms may also show thickening and deformity of the nerve roots, slight posterior disk bulging, etc.

3. *Degeneration with Protrusion (Concealed Disk).* This type simply represents a more advanced stage than the previous category and is preliminary to gross rupture. The contrast medium here is noted to bulge posteriorly into the spinal canal (Fig. 9, L-3). The posterior rim of the annulus fibrosus is intact so that extradural leakage usually is not present. Anterior extension may follow hypertrophic spurs (Fig. 9, 10 and 11, L-3; Fig. 15, L-5). Lateral (Fig. 9) and vertebral protrusions may be visualized. Three to five cc. of contrast material may be injected with ease. Low back pain may be present.

4. *Herniation (Fig. 1, L-4).* Degeneration may also be present. Occasionally some contrast material may be visualized in the disk, the majority being present in the extradural space. The protrusion here is usually much greater than with simple bulging of the disk which is actually a

Fig. 15. Lateral view showing disk degeneration at L-4. Narrow L-5 space with some anterior protrusion and hypertrophic spurs.

precursor to gross rupture. No resistance is encountered during the injection. The patient's symptoms may be reproduced. Three to five cc. or more of contrast material may be injected.

DIAGNOSTIC CRITERIA

The degree of pressure necessary in the injection of diodrast, the amount of contrast material injected, and the presence or absence of symptoms during injection are important diagnostic criteria.

Our experience compares favorably with that of Walk[46] relative to the greater frequency of radiculitis following nuclear injection in the presence of herniated disk. This finding alone, however, does not dictate the need of surgery. Wood[50] feels that this information actually outweighs the roentgen features of the procedure. DeHaene[12] also emphasizes the diagnostic importance of reproduction of pain at the time of injection of the contrast medium. Conversely, radiating pain of this type does not necessarily connote disk protrusion. Lindblom[32] feels that he can distinguish the offending disk at the time of injection by the appearance of symptoms such as low back pain, sciatica, etc. In fact, he believes that the posterior longitudinal ligament is extremely sensitive during piercing with the lumbar puncture needle in the presence of disk pathology. We have not always found this to be so. He also feels that if the typical sciatic pain is reproduced after the first disk injection that no additional punctures are required. We routinely inject at least the fourth and fifth lumbar disks regardless of this point because of the possibility of error in this interpretation and since several disks may be involved. Friedman and Goldner[21] found a positive correlation between reproduction of pain with disk protrusion on subsequent films in a study of 150 cases.

Two additional diagnostic criteria of importance are the configuration of the opaque medium on subsequent films, and the presence of diodrast in the epidural canal.

Caution must be exercised in the interpretation of extradural presence of contrast medium as demonstrated by Gardner, Wise, Hughes, O'Connell and Weiford.[22] They reported that 7 of 46 disks explored from a total of 89 diskograms were negative at operation (15 per cent false positive diagnoses). Five of these which were atypical cases with negative roentgenograms otherwise presented the above finding. It is apparent that the contrast material can leak through the opening in the annulus fibrosus to present such a picture and it might be worth while to reduce this error by leaving the needle *in situ*, insofar as this is possible, while taking routine films.

Walk[46] also cautions on the appearance of rupture with spreading contrast material, as if unassociated with tissue particles. Exploration is not indicated even if typical pain was reproduced at the time of disk puncture.

RESULTS

Gardner, *et al.*[22] explored 48 cases following satisfactory diskography. The operative findings corroborated the roentgenographic data in 39 instances as to pathology and level of the lesion. Pain had been reproduced in one-half of these cases at the time of the disk injection, and in one-third, the opaque substance had been visualized in the epidural space. Two additional cases were explored on the basis of the clinical syndrome in the presence of negative diskograms. No abnormalities were disclosed at surgery. These authors also noted 38 narrowed intervertebral spaces in their 89 diskograms, all of which were due to degeneration with or without posterior protrusion. Of the 39 patients with surgically verified disk lesions mentioned above, 18 had narrowing of the interspace.

Gleason[23] found 8 patients with positive diskograms in a series of 30 injections. Seven of these were operated on with verification of the findings. One was found to have a protrusion not recognized roentgenographically. This was felt to be on

the basis of poor visualization of the interspace. Central injection of the disk was, therefore, emphasized.

Friedman and Goldner[21] studied their results following a review of 150 cases. They commonly injected 3 disks, and occasionally 4. Pain was reproduced in those cases with protrusion. Fifty previous myelograms were available for comparison; agreement was noted in 14, partial verification in an additional 14, and there was no correlation in the remainder.

The myelographic correlation appeared to be higher on utilizing the full column technique according to Fricker[20] particularly in those cases with a bulging annulus.

Davies and Peirce[10] described their results in a series of 23 patients. A second attempt was necessary in 5 instances. Disk disease was identified in 20 cases with a total of 30 lesions. Twelve patients were explored with positive disk correlation.

Walk[46] emphasized the clinical data in a study of 98 disk injections in 67 patients. Two disk syndromes were observed: (1) compression by a non-ruptured disk. Diminution in the Achilles reflex together with subjective and objective sensory disturbances were commonly noted; (2) herniation. Pain on coughing and a positive Lasègue sign were found in a high percentage of cases. In addition to some overlap in these groups, some cases presented patellar reflex changes and paresis of the extensor hallucis longus muscle. Fifteen cases were explored, in 6 of which the surgical findings compared favorably with the preoperative diskogram. One additional patient proved to have a general bulging of the disk without local protrusion. Thickened nerve roots were found in 2 with hypertrophy of the ligamentum flavum in one. The remaining 5 were negative at operation. The myelograms (in 14 cases) correlated favorably with the diskograms in the majority of instances, both negatively and positively. The positive cases commonly exhibited other roentgen changes such as narrowing of the intervertebral space, hyperostoses, etc.

SUMMARY

The respective value of myelography and diskography in the diagnosis of lesions of the intervertebral disk has been stressed. Myelography is still regarded as a very useful diagnostic procedure if carefully performed in spite of adverse comment in past years. It is to be re-emphasized that errors in interpretation will continue to occur if inadequate contrast material is used, insufficient films are taken, incomplete exploration of the veretebral canal is carried out, and if the other limitations enumerated are not recognized and taken into consideration, *e.g.*, anatomic variations, presence of associated pathology, etc.

It is preferred to initiate the patient's investigation with myelography, as a large percentage (over 90 per cent) of patients with a typical clinical history and objective neurologic signs will yield positive roentgen findings. The patients with negative or equivocal myelograms, atypical histories, negative or minimal physical and neurologic findings, with or without radiculitis, and recalcitrant to therapy are recommended for diskography. The history, technique and results utilizing this procedure have been discussed.

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THE ESTIMATION OF SKULL CAPACITY FROM ROENTGENOLOGIC MEASUREMENTS

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HAAS,[2] in a roentgenologic investigation into live skulls, the actual capacities of which could not be known, stated that, "In cases of normal skull configuration the measured length alone characterizes the size of the skull reliably." The length was the measurement from glabella to opisthocranion.

MacKinnon[5] obtained 52 dry adult skulls, demonstrated that they represented a reasonable sample of a mixed adult population, and showed that the average relation of their actual capacities in cubic centimeters to their glabella-opisthocranion lengths in centimeters was 78 to 1. He suggested that multiplication of this roentgenologic length of any skull by 78 would provide the optimum estimated capacity based on length alone, and showed that capacities estimated in this way would be liable to a maximum error of approximately 17.2 per cent.

The object of the present investigation is to relate the known capacities of the same 52 skulls to various easily obtainable roentgenologic measurements, and so to find ways of estimating skull capacities more accurately than from their glabella-opisthocranion length.

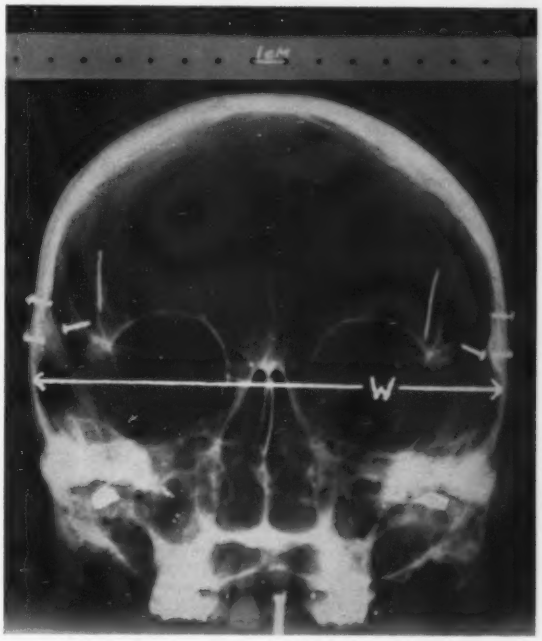

FIG. 2. Anteroposterior roentgenogram showing internal breadth (*W*). The measuring bar is placed above the widest part of the skull.

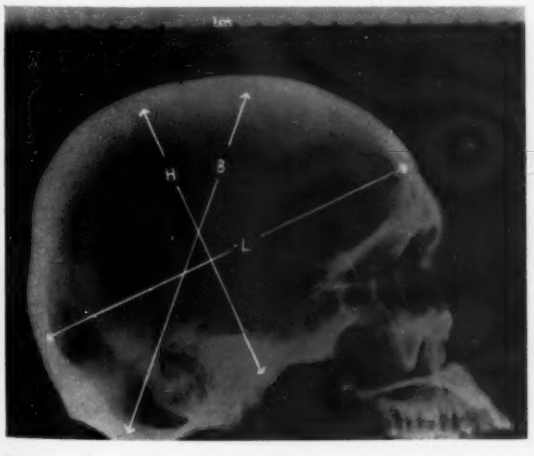

FIG. 1. Lateral roentgenogram showing internal length (*L*), internal height (*H*) and bregma posterior cranial fossa diameters (*B*). The measuring bar is placed above the midline of the skull.

METHODS

Lateral and anteroposterior Potter-Bucky roentgenograms of 52 adult skulls of known capacities[5] were made. During the lateral exposures (Fig. 1) a measuring bar perforated at 1 cm. intervals was suspended above the midline, and during the anteroposterior exposures (Fig. 2) the same measuring bar was suspended above the widest part of the skull. Consequently any measurements in the plane of the midline of the skulls, or in the coronal plane at their widest parts, could be made directly. To ensure

that the external auditory meati would be identifiable in the roentgenograms a small strip of lead was folded on to their anterior margins.

Three internal measurements were obtained from the lateral roentgenograms (Fig. 1) and recorded in Table 1. First, the internal length (*L*) or maximum internal anteroposterior diameter (Column 2). Secondly, the height (*H*) was measured from midway between the lead strips marking the external auditory meati to the farthest point on the inside of the vault of the skull and recorded in Column 5. Thirdly, a measurement (*B*) was taken from inside of the bregma to the posterior cranial fossa and recorded in Column 8. In roentgenograms where the internal tables of the two sides were not superimposed, measurement was made to half-way between them.

From the anteroposterior roentgenograms (Fig. 2) one measurement, the internal breadth, was taken at the widest part of the cavity and recorded in Column 11 of Table 1.

Internal skull diameters were adopted in place of the classic external ones because they represent the true boundaries of the cranial cavity and, roentgenologically, are equally accessible. The particular diameters were chosen because the fundamental shape of the cavity is ellipsoid and the calculation of the capacity of an ellipsoid is based on three diameters at right angles to each other. Hence the choice of length (*L*), height (*H*) and breadth (*W*). The only major departure in the shape of the cranial cavity from that of an ellipsoid is the posterior cranial fossa which consequently had to be taken into account. Therefore, a fourth measurement (*B*) was introduced extending from the posterior cranial fossa to the only suitably placed point commonly visible—the bregma.

Table 1 presents the capacities of the skulls investigated (Column 1). It also presents (Column 2, 5, 8 and 11) the four linear dimensions obtained for each skull with, at the foot of the appropriate columns, the calculated average ratio between the skull capacities (cc.) and their linear measurements (cm.). Estimated capacities based on the average relation of capacity to length are presented in Column 3 with the pertinent percentage errors in Column 4. Estimated capacities based on height (Column 6), bregma to posterior cranial fossa (Column 9) and breadth (Column 12) were calculated in a corresponding manner. The error in each estimate is placed in the subsequent column.

Table 11 was constructed with the object of relating the true capacities of the skulls to three synthetic volumes each based on different combinations of the linear measurements obtained from the 52 skulls. In Column 2 the products of length, height and breadth are presented, in Column 5 the products of length, diameter from bregma to posterior cranial fossa, and breadth are presented, and in Column 8 the average volumes of Column 2 and 5 are presented. Column 8 was introduced because it was noted that twice the true capacities (Column 1) exceeded the volume in Column 2 and were less than the volume in Column 5. Consequently it was expected that a combination of Column 2 and 5 would bear a closer relationship to the true capacity than either column alone. The average ratios of skull capacities to the three volumes were calculated and are presented at the foot of the appropriate columns. Estimated capacities based on length, height and breadth are presented in Column 3 with the errors of the estimates in Column 4. Estimated capacities based on length, bregma-posterior cranial fossa and breadth (Column 6), and on length, height, bregma-posterior cranial fossa and breadth (Column 9) were also calculated and are presented with pertinent errors in the subsequent columns.

The combination of $L \times H \times W$ and $L \times B \times W$ with the least standard deviation was also calculated in the belief that it would form a still better basis for the estimation of skull capacity than an equal combination of the two. The synthetic volumes based on the average relationship of

Table I

THE RELATION OF THE CAPACITIES OF 52 DRY HUMAN SKULLS TO THE LENGTH (L), HEIGHT (H), BREGMA POSTERIOR CRANIAL FOSSA DIAMETER (B) AND BREADTH (W) OF THEIR CRANIAL CAVITIES

Serial No. Skull	Capacity (V) in Cubic Centimeters	Length (L) in Centimeters	$\frac{V}{L \times Av} - \frac{}{L}$	% Departure of Col. 3 from Col. 1	Height (H) in Centimeters	$\frac{V}{H \times Av} - \frac{}{H}$	% Departure of Col. 6 from Col. 1	Bregma to Post. Cr. Fossa (B) in Centimeters	$\frac{V}{B \times Av} - \frac{}{B}$	% Departure of Col. 9 from Col. 1	Breadth (W) in Centimeters	$\frac{V}{W \times Av} - \frac{}{W}$	% Departure of Col. 12 from Co. 1
	Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col. 10	Col. 11	Col. 12	Col. 13
1	1,410	16.8	1,415	0.35	11.4	1,379	2.19	13.8	1,380	2.12	12.75	1,403	0.49
2	1,420	16.0	1,347	5.14	12.0	1,452	2.25	13.8	1,380	2.18	13.2	1,452	2.25
3	1,330	16.1	1,356	1.95	11.4	1,379	3.68	14.0	1,400	5.26	12.95	1,425	7.14
4	1,690	18.2	1,532	9.35	12.8	1,549	8.34	15.45	1,545	8.56	13.3	1,463	13.4
5	1,415	16.5	1,389	1.8	11.9	1,440	1.76	14.9	1,490	5.30	12.4	1,364	3.6
6	1,365	15.25	1,284	5.93	11.75	1,422	4.17	13.3	1,330	2.56	13.1	1,441	5.56
7	1,325	16.75	1,410	6.42	11.15	1,349	1.81	14.5	1,450	9.43	12.2	1,342	1.28
8	1,155	16.0	1,347	16.6	11.0	1,331	15.2	13.5	1,350	16.9	12.1	1,331	15.2
9	1,345	17.0	1,431	6.39	10.85	1,313	2.37	14.1	1,410	4.83	12.25	1,348	0.22
10	1,355	16.0	1,347	0.59	11.4	1,379	1.77	14.1	1,410	4.06	12.9	1,419	4.72
11	1,540	17.0	1,431	7.07	12.35	1,494	2.99	14.9	1,490	3.25	12.4	1,364	11.4
12	1,260	16.0	1,347	6.9	11.1	1,343	6.59	13.6	1,360	7.93	12.95	1,425	13.1
13	1,338	16.6	1,398	4.72	11.1	1,343	0.60	14.0	1,400	4.86	12.75	1,403	5.09
14	1,475	17.0	1,431	2.98	12.0	1,452	1.56	15.2	1,520	3.05	12.4	1,364	7.52
15	1,320	15.8	1,330	0.76	11.8	1,428	8.18	14.1	1,410	6.82	13.0	1,430	8.33
16	1,590	16.9	1,423	10.5	12.5	1,513	4.84	14.2	1,420	10.7	14.0	1,540	3.14
17	1,460	16.5	1,389	4.86	12.4	1,500	2.74	14.6	1,460	6.0	12.5	1,375	5.82
18	1,450	16.8	1,415	2.41	11.4	1,379	4.89	14.0	1,400	3.45	13.2	1,452	0.14
19	1,495	16.8	1,415	5.35	12.0	1,452	2.88	14.9	1,490	0.33	13.0	1,430	4.35
20	1,455	16.9	1,423	2.20	11.1	1,343	7.70	14.2	1,420	2.41	13.0	1,430	1.72
21	1,370	17.4	1,465	6.93	10.6	1,283	6.35	13.3	1,330	2.92	12.3	1,353	1.24
22	1,640	17.5	1,474	10.1	12.1	1,464	10.7	14.3	1,430	12.8	13.0	1,430	12.8
23	1,455	16.9	1,423	2.19	11.8	1,428	1.85	13.6	1,360	6.53	13.3	1,463	5.49
24	1,380	17.2	1,448	4.93	11.3	1,367	0.95	14.2	1,420	2.89	12.9	1,419	2.82
25	1,415	16.6	1,398	1.20	11.9	1,440	1.77	14.1	1,410	.35	12.5	1,375	3.83
26	1,195	16.0	1,347	12.7	10.6	1,283	7.36	13.8	1,380	15.5	12.1	1,331	11.4
27	1,430	16.2	1,364	4.62	11.8	1,428	0.14	14.2	1,420	.70	13.1	1,441	0.77
28	1,285	15.9	1,339	4.2	11.0	1,331	3.57	13.0	1,300	1.17	12.4	1,364	6.15
29	1,300	16.5	1,389	6.85	11.0	1,331	2.38	13.4	1,340	3.07	12.3	1,353	4.08
30	1,125	15.8	1,330	18.2	10.6	1,283	14.0	13.1	1,310	16.4	11.5	1,265	12.4
31	1,285	16.2	1,364	6.15	11.3	1,367	6.38	13.8	1,380	7.39	11.8	1,298	1.01
32	1,365	17.4	1,465	7.33	10.8	1,307	4.24	14.0	1,400	2.56	12.3	1,353	0.88
33	1,150	15.4	1,297	12.8	11.2	1,355	17.8	13.7	1,370	19.1	12.1	1,331	15.7
34	1,510	16.3	1,372	9.14	12.5	1,513	0.19	14.0	1,400	7.28	13.5	1,485	1.65
35	1,290	16.7	1,406	8.99	10.6	1,283	0.54	14.0	1,400	8.53	12.1	1,331	3.18
36	1,605	18.1	1,524	5.05	12.1	1,464	8.78	15.0	1,500	6.54	12.6	1,386	13.6
37	1,490	17.3	1,457	2.21	11.9	1,440	3.36	14.5	1,450	2.68	13.0	1,430	4.03
38	1,585	16.3	1,372	13.4	12.0	1,452	8.39	14.0	1,400	11.7	13.9	1,529	3.53
39	1,700	17.6	1,482	12.8	12.2	1,476	13.2	14.3	1,430	15.9	13.9	1,529	10.1
40	1,560	16.8	1,415	9.29	11.4	1,379	11.6	14.6	1,460	6.41	13.9	1,529	1.99
41	1,485	17.4	1,465	1.35	11.6	1,404	5.45	15.0	1,500	1.01	12.9	1,419	4.44
42	1,300	16.0	1,347	3.62	11.2	1,355	4.23	14.0	1,400	7.69	12.1	1,331	2.38
43	1,200	15.7	1,322	10.2	11.0	1,331	10.9	13.0	1,300	8.33	12.1	1,331	10.9
44	1,310	17.1	1,440	9.92	11.56	1,398	6.72	13.7	1,370	4.58	12.5	1,375	4.96
45	1,290	16.1	1,356	5.12	11.2	1,355	5.04	13.2	1,320	2.32	12.5	1,375	6.58
46	1,300	16.5	1,389	6.84	11.3	1,367	5.15	13.5	1,350	3.84	12.5	1,375	5.77
47	1,325	16.4	1,381	4.23	11.3	1,367	3.18	13.5	1,350	1.88	12.2	1,342	1.28
48	1,340	16.8	1,415	5.59	11.1	1,343	0.22	14.1	1,410	5.22	12.7	1,397	4.25
49	1,285	16.5	1,389	8.09	11.6	1,404	9.26	13.0	1,300	1.16	12.5	1,375	7.0
50	1,630	16.8	1,415	13.2	12.0	1,452	10.9	15.1	1,500	7.36	14.6	1,606	1.47
51	1,525	16.8	1,415	7.21	11.7	1,416	7.14	14.0	1,400	8.19	13.7	1,331	12.7
52	1,540	17.3	1,457	5.39	11.8	1,428	7.27	14.4	1,440	6.49	13.2	1,441	6.15
		$\frac{V}{Av \frac{}{L}} = 84.2 - 1$			$\frac{V}{Av \frac{}{H}} = 121 - 1$			$\frac{V}{Av \frac{}{B}} = 100 - 1$			$\frac{V}{Av \frac{}{W}} = 110 - 1$		

TABLE II

THE RELATION OF TRUE CAPACITIES OF 52 HUMAN SKULLS TO VOLUMES SYNTHESIZED FROM THEIR LENGTHS (L), HEIGHTS (H), BREGMA TO POSTERIOR CRANIAL FOSSA DIAMETERS (B) AND BREADTHS (W)

Serial No. Skull	Capacity (V) in Cubic Centimeters	$L\times H\times W$ cc.	$\frac{V}{\text{Col. 2}\times\text{Av}}$ Col. 2	% Departure of Col. 3 from Col. 1	$L\times B\times W$ cc.	$\frac{V}{\text{Col. 5}\times\text{Av}}$ Col. 5	% Departure of Col. 6 from Col. 1	$\frac{1}{2}(L\times H\times W)+\frac{1}{2}(L\times B\times W$	$\frac{V}{\text{Col. 8}\times\text{Av}}$ Col. 8	% Departure of Col. 9 from Col. 1
	Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col. 10
1	1,410	2,441	1,394	1.13	2,956	1,386	1.70	2,699	1,390	1.76
2	1,420	2,534	1,447	1.90	2,915	1,367	3.73	2,725	1,403	0.63
3	1,330	2,376	1,357	2.03	2,919	1,369	2.93	2,648	1,364	5.19
4	1,690	3,095	1,769	4.67	3,740	1,754	3.79	3,419	1,761	1.92
5	1,415	2,434	1,390	1.76	3,049	1,430	1.06	2,742	1,412	1.42
6	1,365	2,383	1,341	1.75	2,657	1,246	8.72	2,503	1,289	5.57
7	1,325	2,278	1,301	1.81	2,964	1,390	4.90	2,621	1,350	1.87
8	1,155	2,129	1,216	5.28	2,614	1,226	6.15	2,372	1,222	2.85
9	1,345	2,258	1,290	4.10	2,937	1,377	2.37	2,598	1,338	0.52
10	1,355	2,352	1,344	0.81	2,910	1,365	0.74	2,632	1,355	0.0
11	1,540	2,602	1,486	3.51	3,141	1,473	4.35	2,872	1,479	3.96
12	1,260	2,300	1,313	4.21	2,818	1,322	4.92	2,559	1,318	4.60
13	1,335	2,348	1,341	0.45	2,964	1,390	4.12	2,657	1,368	2.47
14	1,475	2,529	1,444	2.10	3,204	1,503	1.90	2,867	1,477	0.14
15	1,320	2,423	1,384	4.85	2,896	1,358	2.88	2,660	1,370	3.78
16	1,590	2,957	1,688	6.16	3,360	1,576	0.88	3,159	1,626	2.26
17	1,460	2,557	1,460	0.0	3,012	1,413	3.22	2,785	1,434	1.78
18	1,450	2,527	1,443	0.48	3,105	1,456	0.41	2,817	1,451	0.07
19	1,495	2,620	1,496	0.06	3,254	1,526	2.07	2,937	1,513	1.20
20	1,455	2,437	1,393	4.26	3,120	1,463	0.55	2,780	1,432	1.58
21	1,370	2,268	1,295	5.47	2,846	1,335	2.55	2,557	1,317	3.87
22	1,640	2,752	1,571	4.21	3,253	1,526	6.95	3,003	1,547	5.67
23	1,455	2,652	1,514	4.05	3,057	1,434	1.44	2,855	1,470	1.03
24	1,380	2,506	1,431	3.70	3,150	1,477	7.03	2,828	1,456	5.51
25	1,415	2,469	1,410	0.35	2,925	1,372	3.02	2,697	1,389	1.83
26	1,195	2,052	1,172	1.92	2,672	1,253	4.85	2,362	1,216	1.76
27	1,430	2,522	1,430	0.0	3,013	1,413	1.19	2,759	1,421	0.63
28	1,285	2,169	1,238	3.65	2,564	1,203	6.38	2,367	1,219	5.14
29	1,300	2,232	1,274	2.0	2,719	1,275	1.92	2,476	1,275	1.92
30	1,125	1,925	1,100	2.22	2,380	1,116	0.80	2,153	1,109	1.42
31	1,285	2,159	1,233	4.05	2,639	1,238	3.65	2,399	1,235	3.89
32	1,365	2,311	1,320	3.29	2,996	1,405	2.93	2,654	1,367	0.15
33	1,150	2,087	1,192	3.65	2,552	1,197	4.09	2,320	1,195	3.91
34	1,510	2,750	1,570	3.97	3,081	1,445	4.30	2,916	1,502	0.53
35	1,290	2,142	1,223	5.19	2,829	1,327	2.87	2,486	1,280	0.78
36	1,605	2,759	1,575	1.86	3,422	1,605	0.0	3,091	1,592	0.81
37	1,490	2,677	1,529	2.62	3,261	1,529	2.62	2,969	1,529	2.62
38	1,585	2,719	1,553	2.01	3,172	1,488	6.12	2,946	1,517	4.29
39	1,700	2,984	1,704	0.24	3,498	1,641	3.47	3,241	1,669	1.82
40	1,560	2,662	1,520	2.65	3,409	1,599	2.50	3,036	1,564	0.26
41	1,485	2,603	1,486	0.07	3,368	1,580	6.40	2,986	1,538	3.57
42	1,300	2,168	1,238	4.77	2,710	1,271	2.23	2,439	1,256	3.38
43	1,200	2,090	1,193	0.58	2,470	1,158	3.50	2,280	1,174	2.17
44	1,310	2,471	1,411	7.71	2,929	1,374	4.89	2,700	1,391	6.18
45	1,290	2,253	1,286	0.31	2,657	1,246	3.41	2,455	1,264	2.02
46	1,300	2,331	1,331	2.38	2,785	1,306	0.46	2,558	1,317	1.31
47	1,325	2,261	1,291	2.56	2,701	1,267	4.37	2,481	1,278	3.55
48	1,340	2,369	1,353	0.97	3,009	1,411	5.30	2,689	1,385	3.36
49	1,285	2,393	1,366	6.30	2,682	1,258	2.10	2,538	1,307	1.71
50	1,630	2,943	1,680	3.07	3,704	1,737	6.56	3,324	1,712	5.03
51	1,525	2,693	1,538	0.85	3,223	1,512	0.85	2,968	1,529	0.26
52	1,540	2,694	1,538	0.13	3,288	1,542	0.13	2,991	1,540	0.0
			$\text{Av}\frac{V}{L\times H\times W}=0.57$			$\text{Av}\frac{V}{L\times B\times W}=0.47$			$\text{Av}\frac{V}{\frac{1}{2}(L\times H\times W)+\frac{1}{2}(L\times B\times W)}=0.51$	

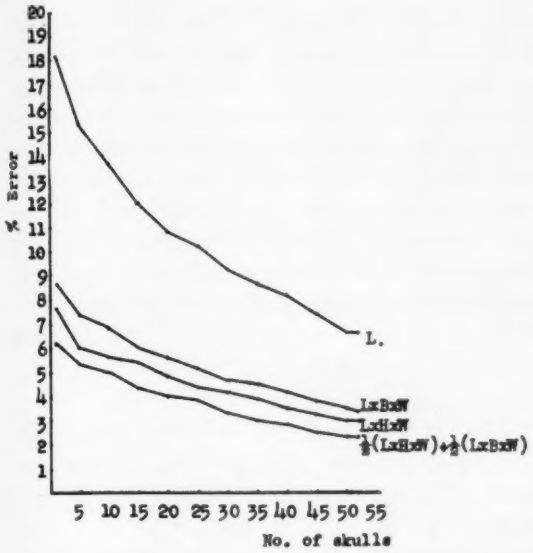

Fig. 3. Graphs of maximum errors obtained in estimating the capacities of 52 skulls from their roentgenologic length (L), and from combinations of length (L), height (H), bregma posterior cranial fossa diameter (B) and breadth (W).

this combination to the capacities are not reproduced.

Figure 3 was devised to illustrate graphically the maximum errors experienced in estimating skull capacity from roentgenologic length (L), and from combinations of length (L), height (H), bregma-posterior cranial fossa diameter (B) and breadth (W). For example, the graph L was constructed from Table I, Column 4 and records the worst error, the average of the five worst errors, the average of the ten worst errors, and so on. The graph $L\times B\times W$ was formed by similar treatment of Column 7 in Table II and the graphs $L\times H\times W$ and $\frac{1}{2}(L\times H\times W)+\frac{1}{2}(L\times B\times W)$ were drawn from Column 4 and 10, respectively.

Table III was constructed in order to present the multiples by which it was found appropriate to convert the linear roentgenologic measurements, and combinations of them, into optimum estimated capacities, and to record the range of error which resulted from the use of each as a basis for the estimation of skull capacity.

RESULTS

Table I, Column 2 shows that the internal lengths of the skulls varied from a minimum of 15.25 cm. to a maximum of 18.2 cm. The average relationship between their capacities in cubic centimeters and their lengths in centimeters was calculated to be 84.2 to 1. Estimated capacities (Column 3) based on length$\times$84.2 differed from the true capacity to the greatest degree in serial No. 30 where the difference amounted to 18.2 per cent (Column 4). Table I also shows that the calculated average ratios of the capacities of the skulls to their heights, bregma-posterior cranial fossa measurements and breadths were 121 to 1, 100 to 1 and 110 to 1, respectively. Estimated capacities (Column 6, 9 and 12) based on their linear measurements differed maximally from the true capacities in serial No. 33 where the departures amounted to 17.8

Table III

Multiples with which various measurements obtained from skull roentgenograms can be converted into estimated skull capacities (cc.), with the range of possible errors in the estimates

	Multiple	% Error 1 skull	% Error 50 skulls
Length in cm. (L)	84.2	0–18.2	0–6.7
Height in cm. (H)	121.0	0–17.8	0–5.7
Bregma to Post. Cranial Fossa in cm. (B)	100.0	0–19.1	0–6.3
Breadth in cm. (W)	110.0	0–15.7	0–5.7
$L\times B\times W$ in cc.	0.47	0– 8.72	0–3.5
$L\times H\times W$ in cc.	0.57	0– 7.71	0–3.0
$\frac{1}{2}(L\times H\times W)+\frac{1}{2}(L\times B\times W)$ in cc.	0.51	0– 6.18	0–2.4

per cent (Column 7), 19.1 per cent (Column 10) and 15.7 per cent (Column 13), respectively. These departures are of a size which would exceed 200 cc. in average skulls of 1,400 cc.[1] and are of such magnitude that the estimated capacity of a single skull based on a single internal roentgenologic measurement is of no value.

When, however, the average capacity of fifty skulls was estimated from a single roentgenologic linear measurement, the maximum error admitted was found to be reduced to between 5.7 per cent and 6.7 per cent (Table III), that is, the error ranged between zero and 94 cc. in skulls with an average capacity of 1,400 cc. This moderate error indicated that any of the linear measurements formed a reasonable basis for the estimation of the average capacity of 50 or more of the skulls.

Table II, Column 2 contains a volume synthesized from length (L), height (H) and breadth (W) for each skull. The average relation between the true skull capacities and the synthesized volumes was calculated to be 0.57 to 1. The greatest difference between the estimated skull capacities (Column 3) obtained from $(L\times H\times W)\times 0.57$ and the true capacities was found in serial No. 44, and was 7.71 per cent (Column 4). That is, the range of error in the estimation of the capacity of a single skull from these three measurements was zero to 108 cc. in a skull of average size (1,400 cc.).

Table II, Column 5 contains the product of length (L), diameter from bregma to posterior cranial fossa (B) and breadth (W) for each skull. The average ratio of true skull capacity to these products was calculated to be 0.47 to 1. Estimated capacities (Column 6) based on $(L\times B\times W)\times 0.47$ differed maximally from the true capacity in Serial No. 24, the amount being 7.03 per cent (Column 7). Therefore, the error introduced by using these three measurements as a basis for estimating the capacity of a single skull was between zero and 122 cc. in a skull of average size.

Table II, Column 8 contains a volume synthesized from equal parts of $L\times H\times W$ and $L\times B\times W$ for each skull. The average relation of the true capacity of the skulls to their synthetic volumes was calculated to be 0.51 to 1. Estimated capacities (Column 9) based on the synthetic volumes in Column 8×0.51 differed maximally from the true capacities in Serial No. 44, the amount being 6.18 per cent (Column 10). Therefore, the error introduced into the estimation of the capacity of a single skull of average size on the basis of equal parts of $L\times H\times W$ and $L\times B\times W$ was zero to 87 cc.

The combination of $L\times H\times W$ and $L\times B\times W$ with the least standard deviation was calculated to be $8/10(L\times H\times W)+2/10(L\times B\times W)$. Estimated capacities based on this combination were found to have an average error of 2.52 per cent and a maximum error of 7.18 per cent. Clearly its use had no advantage over the formula based on equal amounts of L, H, W, and L, B, W, and the detailed figures were therefore not reproduced.

Figure 3 demonstrates that the maximum error obtained in estimating the capacity of a single skull from a single roentgenologic diameter (L) was very large; that the maximum error in estimating the average capacity of 50 skulls from a single diameter was moderate; that the maximum error in estimating the capacity of a single skull from combinations of three or of four linear dimensions was moderate; and that four diameters are better than three.

DISCUSSION

Classic investigations of the relation of the measured capacity of dry skulls to their linear diameters commonly employed combinations of two or three external diameters chosen from length (glabella to opisthocranion), maximum breadth, auricular height (top of external auditory meatus to vault, at right angles to a line from the top of the external auditory meatus to the inferior orbital margin), and total height (basion to bregma), and converted them into estimated capacities in various ways.[6] Eventually Lee,[4] employing length, breadth

and auricular height, developed a formula for females of mixed races and a formula for males of mixed races which were reported to admit an average error of 2.4 per cent with a maximum error of 4 per cent. In the present investigation a combination of the diameters (L), (H) and (W), which were internal measurements but otherwise comparable to those used by Lee, was found to admit the somewhat larger average error of 2.7 per cent with a maximum error of 7.71 per cent. The introduction of the fourth diameter—bregma to posterior cranial fossa—reduced the average error to 2.2 per cent which is somewhat smaller than that obtained by Lee, but the maximum error—6.18 per cent—remained higher than Lee's.

Lee's formulas were based on the mathematical theory[3] that, when a linear relationship exists between two sets of observations, the relation is best expressed as a regression equation; that is, in the belief that $cap = K_1 + (K_2 \times synth\ vol.)$ was likely to be a better expression of the relationship of true capacity to synthetic volume than $cap = K \times synth\ vol.$, K, K_1 and K_2 being constants. The latter equation was used in the present investigation, in the first instance because of its relative simplicity; secondly, in the belief that a regression equation would be less valuable to the present case because direct measurements of the cranial cavity were made in place of the indirect ones used by earlier observers; and thirdly, in the knowledge that a regression equation does not *a priori* take precedence in accuracy in the expression of a linear combination of two independent sets of observations. But, since a regression equation has become the accepted basis for the estimation of skull capacity from its external diameters, one was calculated for the relation of the capacities of the skulls of the present series to the synthetic volumes $\frac{1}{2}(L \times H \times W) + \frac{1}{2}(L \times B \times W)$ obtained from internal measurements, with a view to finding whether or not its use would reduce the error in calculating skull capacity. The equation $C - \bar{C} = R(\sigma 1/\sigma 2)(V - \bar{V})$ where C = capacity, V = synthetic volume and R = correlation coefficient was used, and the formula obtained was $cap = 478 + .342\{\frac{1}{2}(L \times H \times W) - \frac{1}{2}(L \times B \times W)\}$. The use of this formula in the calculation of the capacities of the skulls employed in the present investigation was found to introduce an average error of 3.2 per cent with a maximum of 11.6 per cent. Therefore, no advantage was gained by using the additional constant.

It was previously shown that the skulls used in the present investigation represent a reasonable sample of the adult population,[5] and the demonstration by the present investigation that their capacities in cubic centimeters are best calculated from $\{\frac{1}{2}(L \times H \times W) + \frac{1}{2}(L \times B \times W)\} \times 0.51$ when the four roentgenological measurements (cm.) are available indicates that this method is a reasonable one for estimating the capacity of any normal skull, irrespective of sex, to within an error of 6.18 per cent.

The present investigation has also shown that any one of the four adopted roentgenologic skull diameters formed a reasonable basis for the estimation of the average capacity of a group of 50 or more skulls, and the fortuitous fact that the average ratio of the true capacities of the skulls (cc.) to the bregma posterior cranial fossa measurements (B) was 100 to 1 points to that measurement in centimeters as being the one of choice for estimating average capacity from one diameter because of the simplicity of calculating average capacity from $\Sigma(B \times 100)/N$, where N is the number of skulls and exceeds 50.

SUMMARY

1. Fifty-two skulls, of known capacity, believed to constitute a reasonable sample of a mixed adult population, were obtained.

2. A lateral roentgenogram with a measuring bar above the midline and an anteroposterior roentgenogram with a measuring bar above the widest part were made of each skull; their internal lengths (L), internal heights (H), diameters from bregma to

posterior cranial fossa (B) and breadths (W) measured; the average ratio of the skull capacities (cc.) to the various linear measurements (cm.) and to various combinations of them were calculated; and the ratios used to convert the linear measurements and their various combinations into estimated capacities.

3. Estimated capacities based on any one of the four linear diameters were of no value.

4. The estimated average capacity of any 50 of the skulls, based on any one of the four diameters involved a moderate error of 0 to 6.7 per cent.

5. The optimum estimate of the capacity of any one of the skulls from a combination of L, B and W in centimeters was obtained from $(L\times B\times W)\times 0.47$ and was subject to an error of 0 to 8.72 per cent, that is, 0–122 cc. in a 1,400 cc. skull, while the optimum estimate from a combination of L, H and W in centimeters was obtained from $(L\times H\times W)\times 0.57$, and was subject to an error of 0 to 7.71 per cent, or 0–108 cc. in the same size of skull.

6. The optimum estimate of the capacity of any one of the skulls from a combination of L, H, B and W in centimeters was obtained from $\{\frac{1}{2}(L\times H\times W)-\frac{1}{2}(L\times B\times W)\}\times 0.51$, and was subject to an error of 0 to 6.18 per cent (0–87 cc. in a 1,400 cc. skull).

7. It was suggested that a reasonable estimate of the capacity (cc.) of any adult skull can be obtained from the four internal roentgenologic diameters (cm.) used in the present investigation by calculating $\{\frac{1}{2}(L\times H\times W)+\frac{1}{2}(L\times B\times W)\}\times 0.51$.

8. It was further suggested that, in anthropologic investigation, a reasonable estimate of the average capacity of 50 or more skulls (cc.) can be obtained from one linear roentgenologic measurement—the bregma posterior cranial fossa diameter (cm.)—by calculating $\Sigma(B\times 100)/N$, where N = the number of skulls.

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STUDIES IN STEREOENCEPHALOTOMY

V. Roentgenologic Localization of Lesions or Implanted Electrodes*

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IN OUR experience, the preoperative determination of the coordinates of a planned lesion proved sufficiently exact if reference points located in the median plane of the skull were visualized by roentgen examination and the distance of the area to be studied or injured from this reference point was determined from our atlas.[2] If the median plane of the patient is kept parallel to the roentgen film and the distances between focal spot of the roentgen tube, median plane of the patient and film are kept constant, there is a constant relationship between the size of the roentgenographic shadows and the actual size of the structures in the median-sagittal plane so that the points and depths of insertion of an electrode can be easily computed from the measurements on the film. If one tries to determine the position of a pantopaque drop injected at the site of a lesion or of an electrode located at some unknown distance from the median-sagittal plane, one has to take into account that the ratio between the size of the object and that of the image varies depending on the distance of this object from the median-sagittal plane and from the roentgen film. This difficulty can be overcome relatively easily by using the following method which makes accessory charts or devices as used by Mark, McPherson and Sweet[1] for correcting distortions in cranial roentgenograms dispensable.

To the frame of the stereoencephalotome, plexiglass plates are fixed in which wire right angles (w) are imbedded, the vertical sides of which are parallel to and equidistant from the vertical bars to which the plate is fixed (Fig. 1). The horizontal sides of the right angles are directed in opposite directions in the plates that face each other and are equidistant from the upper horizontal bars of the frame. For the anteroposterior as well as for the lateral roentgenograms (Fig. 2) the roentgen tube is located in such a way that its focal spot S is as nearly in line as possible with the vertices of the right angles w_1, w_2 and w_3, w_4 respectively (Fig. 3). The distances between film and frame (Fi_2w_2 or $Fi_1w_4 = c$) and between frame and a plane passing through S parallel to the film (Aw_1 or $Aw_3 = a$) are kept constant. A band holds the frame so that its feet touch the film cassette and the wire

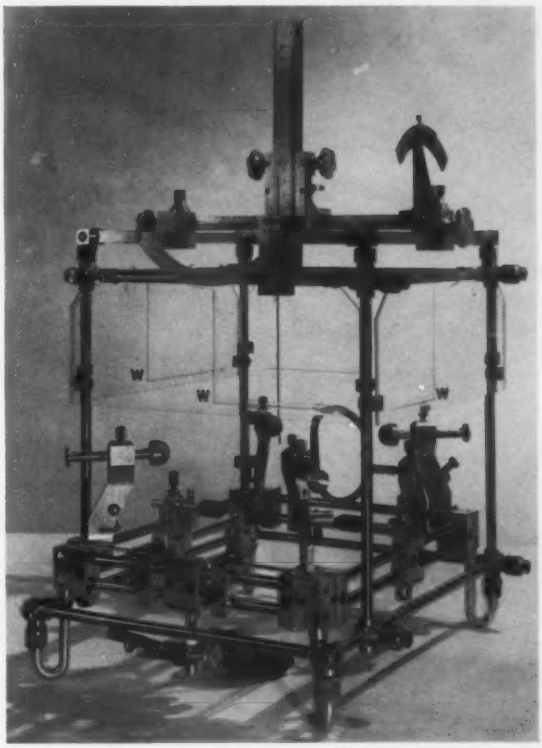

FIG. 1. Stereoencephalotome. Plastic plates with imbedded wire right angles (w) are attached to its frame.

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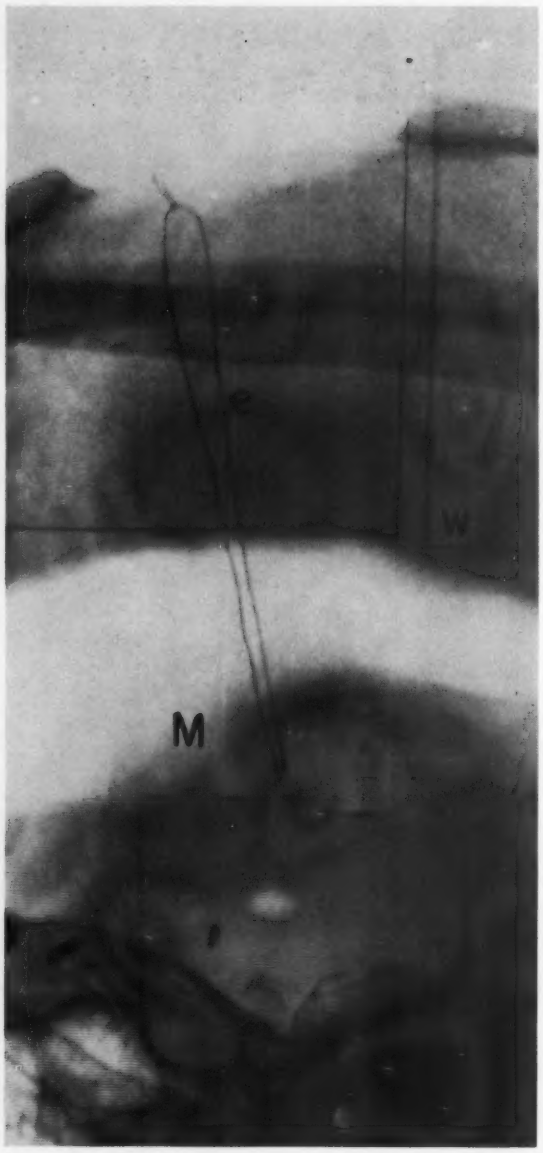

FIG. 2. Lateral roentgenogram showing implanted electrodes (e), wire right angles (w) and reference point (foramen of Monro, M).

right angles facing the film are kept parallel to it. It is important to note which side of the frame faces the film (frontal or occipital, left or right side) so that the path of the roentgen ray beam can later be constructed in relationship to intracranial points.

On the roentgen films one determines the relative positions and distances of the images (P' or P'') of a point p under study and of the vertical sides of the right angles w_1, w_2 or w_3, w_4, and one marks their positions in a diagram representing the actual relationships between focal spot S, the frame with the wire right angles and the film, for the lateral as well as for the anteroposterior roentgenograms (Fig. 3). The side of the frame facing the film must be the same in the diagram as it was during the exposure.

The paths of the roentgen ray beams are constructed by connecting S with P' and P''. The point where the lines SP' and SP'' intersect, represents the actual position of p, in its relationship to the lines w_1–w_2 and w_3–w_4, which correspond to the median

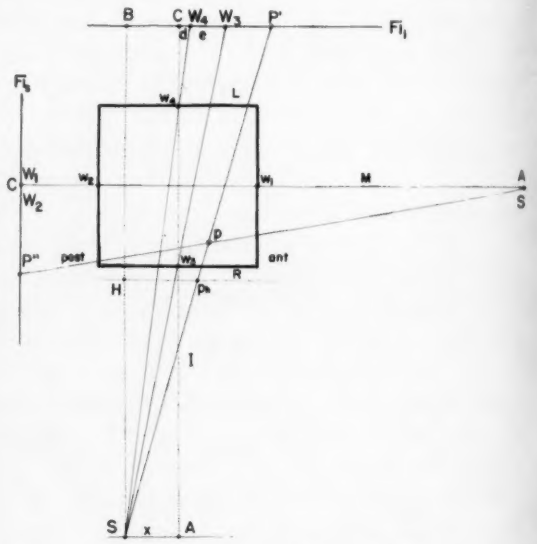

FIG. 3. Diagram showing construction of the position of an intracranial point (p) in relation to the vertical sides of the wire right angles (w_1 to w_4) and to the interaural (I) and the median sagittal (M) planes. AC line represents the median (M) and interaural (I) planes passing through w_1–w_2 and w_3–w_4 respectively. B-H-S line is parallel to AC at distance x; d=distance between C and W_4; e=distance between W_3 and W_4; Fi_1 film, lateral roentgenogram; Fi_2 film, anteroposterior roentgenogram; HP_h line lies at half the distance AC; L=side of frame corresponding to left side of head; P', P'' images of point p; R=side of frame corresponding to right side of head; S focal spot of the roentgen tube; W_1 to W_4 images of vertical sides of wire right angles; x=distance between A and S.

sagittal and the interaural plane of the head respectively. The same can be done for the reference point (anterior or posterior commissure) or any other point, so that the relationship of p to the reference point, or to the electrode, that is placed at the intersection of the median and interaural planes, or to any other point can be determined.

It is not necessary that S lie exactly in the line AC passing through w_1, w_2 or w_3, w_4. If S lies outside this line, so that for instance the projections W_3, W_4 do not coincide, one determines the distance e between W_3 and W_4. The image of the wire that is closer to C is thinner and sharper (W_4) than that of the more distant wire (W_3). Since the distances Aw_3 ($=a$), w_3w_4 ($=b$) w_4C ($=c$) are kept constant, the distance x of the focal spot S from A can be determined according to the formula: $x=eK_1$ and the distance d of C from W_4, according to the formula: $d=eK_2 \cdot K_1$ and K_2 can be determined once and for all for a special setting by constructing a diagram similar to Figure 2 in the actual dimensions and by drawing the lines SW_3 and SW_4 for various positions of S and measuring d, e and x. It is obvious from the diagram that the focal spot of the roentgen tube S and the images W_3, W_4 lie on opposite sides of the AC line. K_1 and K_2 can also be determined mathematically according to the formulas*:

$$K_1=\frac{a}{b}\cdot\frac{a+b}{(a+b+c)}; \qquad K_2=\frac{ac}{b(a+b+c)}$$

For our arrangement $a=82.1$ cm., $b=26.5$ cm., $c=6.4$ cm., and $K_1=2.9$, $K_2=0.17$.

*These formulas were obtained by starting from the equations:

$$\frac{x}{a}=\frac{d+e}{b+c} \text{ (in the triangles } Aw_3S \text{ and } Cw_3W_3) \qquad (1)$$

$$\frac{x}{a+b}=\frac{d}{c} \text{ (in the triangles } Aw_4S \text{ and } Cw_4W_4) \qquad (2)$$

$$x=a\frac{d+e}{b+c}=(a+b)\frac{d}{e} \qquad (3)$$

From the last equation d was determined as a function of a, b, c and e and then the formula for x was obtained by substituting the formula for d in equation 3.

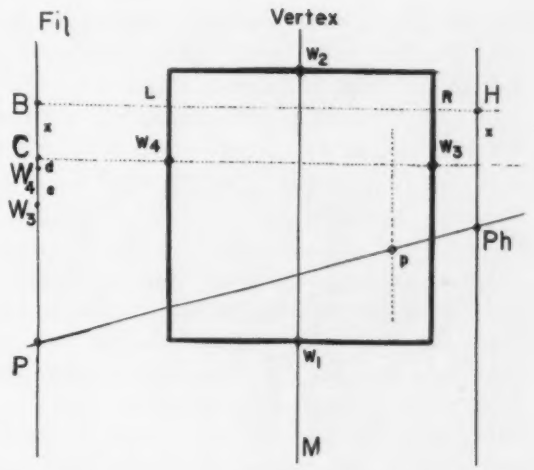

Fig. 4. Construction of the position of an intracranial point (p) in relation to the horizontal sides of the wire right angles (w_3, w_4) and to the median plane (passing through w_1, w_2) using the images on the lateral roentgenogram (Fi_1). Other abbreviations same as in Figure 3.

The drawing of a diagram corresponding to Figure 2 in the natural dimensions requires, of course, a plotting board and drawing paper of considerable size. In our case, for instance, the distance AC is 115 cm. However, plotting board and drawing paper of a little more than half this size are sufficient, without reduction of the actual distances, if one draws a line parallel to AC at the distance x from w_3C, and another line parallel to the film through H, the distance BH being one half of AC. Since the triangles $P'BS$ and P_hHS are similar, HP_h is one half of BP'. Thus if one halves the distance BP' and marks this half distance on the H line, the lines connecting P' and P'' with the corresponding points at the H lines are identical with the lines originating in S, and it is unnecessary to draw the part of the lines between S and the H line.

In order to determine the vertical distance of a point p from the horizontal sides of the right angles, one can use anteroposterior or lateral roentgenograms. The latter are preferable, because they visualize the reference points simultaneously with the implanted electrodes or the pantopaque droplets injected at the site of the lesion.

On the lateral roentgenogram one measures the distance e between the images of the horizontal sides of the right angles (W_3, W_4) and computes from e their distance d from the line w_3C as well as x (distance of B from C and of H from the w_3C line) using the previously mentioned formulas. Then one marks P, W_3, W_4 on the film line Fi_1 in a diagram (Fig. 4) similar to that used for the determination of the horizontal distances from the vertical lines, and also H and P_h on the H line ($HP_h = \frac{1}{2}BP$,) so that the line connecting P_h and P is obtained. The distance of p from the median sagittal plane of the skull is determined from the drawing showing its relationship to the vertical sides of the right angles. Corresponding to this distance, a line is drawn parallel to the median plane. The point where this line intersects with the P_hP line, shows the position of p. Similarly the position of the reference point r and thus the vertical distance between p and r can be found. In a similar way, one can use the anteroposterior roentgenogram for a duplicate determination of the vertical distance of p from the horizontal sides of the right angles. The vertical distance obtained in the lateral and the anteroposterior roentgenogram should, of course, be identical.

SUMMARY

In order to localize pantopaque drops injected at the site of stereotaxically produced intracranial lesions or implanted subcortical electrodes, lateral and anteroposterior roentgenograms of the skull are taken with the stereoencephalotome in position.

By determining the relative position and distances of the images of points under study from the images of wires attached to the frame of the steroencephalotome and constructing the paths of the roentgen ray beams, the actual position of these points in relation to cranial reference planes and intracranial reference points is obtained.

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THE ROLE OF THE EMERGENCY SKULL ROENTGENOGRAM IN HEAD TRAUMA*

By ELMER G. ST. JOHN, M.D.

A GREAT many suspected cranial injuries are seen in the emergency rooms of general hospitals. These patients are often sent to the radiologic departments of these institutions with the request that plain films of the skull be taken and interpreted as an emergency procedure. An evaluation of this practice is the subject of this report.

REVIEW OF LITERATURE

Seletz[19] in a recent article states that he rarely takes skull roentgenograms until the patient is recovering. Lisle[11] delays the skull films until the general condition of the patient improves, since the brain injury is more significant than the skull fracture.

Northfield[16] believes that a roentgen examination of the skull is unnecessary in the early stages in the case of closed head injuries. He states that roentgenograms do not influence treatment, the manipulation of the head may interfere with the airway and that good definition cannot usually be obtained because of the patient's restlessness. He believes, however, that if surgery is to be performed for a fracture, depressed or open, good roentgenograms are essential in order to provide the surgeon with precise information about the site and size of the fracture and the presence of driven-in fragments.

Chambers[2] believes that rest is of paramount importance in the treatment of cerebral injury. He thinks that a portable film may be made occasionally, but that it is usually not important to obtain routine roentgenograms of the skull often taken in the main radiologic department during the first twenty-four hours after the injury.

Ulin, Olsen and Martin[20] state that a skull fracture alone may constitute a minor injury. However, the fracture may assume serious prognostic significance in that it is often associated with severe cerebral or extracranial injury. These authors found that in their series the mortality rate in patients having cerebral injury without skull fracture was 5.7 per cent and with skull fracture it was 26.1 per cent. They believe that roentgenograms of the skull should be taken some time during the patient's hospital stay, but not until after the critical period had passed. The old admonition, that taking roentgenograms in the seriously injured patients should be condemned, must be challenged since accurate roentgenographic diagnosis is essential in the proper management of some patients, whether in shock or not, especially when the chest or abdomen is involved.

Evans and McLaurin[4] state that, in general, roentgen examinations should be deferred until the patient's condition is satisfactory enough to stand a trip to the radiologic department. They believe that the urgency depends on circumstances but a roentgen examination should be made at some point in the course of treatment partly for medicolegal reasons.

Matson,[12] speaking of children, feels that roentgenograms of the skull may be very important in disclosing certain types of depressed and compound fractures not otherwise recognized. However, they seldom contribute any essential information in the acute phase of injury and are contraindicated in a frightened, overactive, unmanageable child or in the presence of shock or a poor airway, in which case they should be delayed until the child's condition has become stabilized.

Dandy[3] thinks that the roentgenographic demonstration of skull fractures is of more interest than importance. Depressed fractures can usually be demonstrated by palpation, but it may be of additional help to visualize roentgenographically the exact in-

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tracranial depth of the fractured fragments.

Trotter, as quoted by Kennedy and Wortis[10] in reference to subdural hematoma, states that an associated skull fracture may rarely be present and that this is more likely in the acute cases in this situation. Wechsler,[22] along with other authors, emphasizes the importance of injury to the brain, meninges, cerebral and meningeal vessels and to the cerebral nerves, and the significance of prolonged unconsciousness regardless whether or not a fracture is present; yet many physicians continue to attach undue importance to the fracture itself. He also states[23] that roentgenography of the skull should never be omitted if for no other than medicolegal reasons.

Walker[21] does not take routine skull roentgenograms as an emergency procedure in cases of head trauma. Only if intracranial bleeding is suspected and the patient is going to the operating room for an exploratory craniotomy or if there are extensive scalp lacerations with a depressed skull fracture are roentgenograms made immediately upon admission to the hospital. In such cases the roentgen examination is carried out on the way to the operating room. In all other instances the films are taken several days or several weeks after the injury simply for medicolegal purposes.

Fay[6] advocates that roentgenograms of the head and other parts of the body be taken only if absolutely necessary to locate foreign bodies or the bone fragments in marked depression. He believes that evidence of a skull fracture offers no aid to treatment unless compounded or greatly depressed. Roentgenograms taken on the second, third or fifth day after the injury serve to confirm the patient's diagnosis, are excellent legal records and spare the patient from additional shock as well as the roentgenologist from a difficult duty usually requiring repetition. Patients do not die from fracture of the skull. They do, however, die from shock, edema and intracranial hemorrhage. Unless compounded or depressed, the point and extent of the fracture do not usually indicate the site of the greatest brain damage. Too frequently laceration and hemorrhage are extensive and contrecoup. He states that frequent neurologic examination and careful observation of progressive signs will determine the location and the necessity for surgical intervention rather than roentgenographic evidence alone. Too frequently much valuable time is lost by sending the patient to the radiologic department, when delay in necessary treatment may mean a life. He further states[7] that roentgenography of the skull should not be undertaken until the patient is entirely out of shock or in a favorable clinical state, with two exceptions: compounded, comminuted fractures where surgery may be required for the sake of proper débridement of the wound and localization of bone fragments; and suspected subdural hematomas where the position of the pineal gland may often be of great assistance. He has seen patients with large skull fractures with few or no cerebral symptoms, and also has seen patients where no demonstrable fracture could be shown roentgenographically with the most profound cerebral injuries and manifestations. The neurologic examination usually suffices to determine the location of the most important areas of involvement and only rarely is a surgeon required to seek immediate roentgenographic assistance for the possible location of a lesion.

Bertrand[1] feels that when time and circumstances permit, plain roentgenograms of the skull should be obtained. He believes that the discovery of a linear fracture points to the most probable site of bleeding. A depressed fracture or a severe fracture of the paranasal sinuses may be detected. Pineal shift is rare in the acute phase.

Hardy[8] advises that roentgenograms of not only the skull but the cervical spine as well be taken early if there are no contraindications. Depressed fractures and linear fractures crossing arterial grooves and sinuses will be clearly demonstrated, aiding in the treatment of the patient.

Horrax and Coleman[9] recommend that in the presence of multiple or possibly pene-

trating wounds of the calvarium, roentgenograms of the skull should be taken to rule out fracture or retention of a foreign body. The inference is that these films should be taken immediately and should be part of the neurologic examination.

Murphy[15] mentions that a depressed skull fracture may be palpable, although roentgen confirmation is usually necessary because of confusion with pericranial hematoma. It is rare to have a head injury of significance without external signs of trauma, cuts, bruises, or scalp depressions.

Ritvo[17] states that there has been considerable controversy in the literature as to the time when roentgen studies of the skull in cases of suspected fracture should be made. If the patient's condition permits, they should be taken soon after the trauma. In those who are comatose, irrational, or in severe shock, the examination may well be delayed until improvement occurs. A complete study is best made with a cooperative individual who can assume the necessary positions and lie quietly during the exposures. Turning of the head and manipulation are essential to complete roentgen study. Attempts at restraint of irrational, struggling patients may do harm. Portable films are seldom satisfactory. There are times when an incomplete roentgenographic study can be important as, for example, in demonstrating a pineal shift in questionable subdural hematoma. In compound or depressed fractures, roentgen studies afford an indication of the severity of the fracture and help in planning the surgical approach or other methods of therapy. With proper selection of cases by the neurosurgeon in close cooperation with the clinician and radiologist, much may be accomplished in cases of this type.

Segerberg and Spurling[18] are of the opinion that clear roentgenograms are likely to be of diagnostic aid, but that the difficulty of obtaining them in a confused or disoriented patient far outweighs their possible value. These authors believe that their chief usefulness is in the demonstration of depressed fractures of the skull or of linear fractures crossing the groove of the middle meningeal artery.

Mock[13] makes the statement that the majority of deaths from skull fractures and brain injuries occur in the first twenty-four hours, depending upon the efficiency of the management. In his series, 64 per cent of the total number of fatal cases died within the first twenty-four hours, while 60 per cent of these first day deaths occurred in the first six hours following the injury. Thus, it is evident that the type of management rendered during the first twenty-four hours, and especially during the first six hours, spells life or death for many of these patients.

Fager[5] thinks that newer methods of diagnosis and therapy have made some of the older rules governing head injuries obsolete and permit an early diagnosis of the type of traumatic lesion present in a given case. Skull roentgenography once was an exhausting and precarious procedure for the patient with a serious head injury in critical condition. The manipulations of the head and neck required previously were entirely too dangerous to the patient's life. However, now entirely satisfactory diagnostic films of the skull can be obtained by means of a grid cassette, without even moving the patient from the transporting litter. Because of this, it is entirely feasible to admit the patient by way of the radiologic department provided that a neurosurgeon is present to attend to the basic needs of the individual and direct the procedure.

According to Munro[14] there are two conditions in which diagnostic roentgen studies are imperative at the earliest possible moment. The first is when a fracture into one of the air sinuses is suspected, since immediate institution of proper treatment here may prevent the onset of meningitis. The other is whenever the surgeon has reason to suspect the presence of an extradural hemorrhage. Under these circumstances, the surgeon will usually have to be content with a single film. To have this film satisfactory and of diagnostic significance, he must be prepared to tell the roentgenologist the area

of the skull that he wants to study, must be willing to assume responsibility for moving the patient to the radiologic room, and must cooperate with the roentgenologist in holding recalcitrant patients' heads quiet, by force if necessary, during the exposure. In return for that the surgeon can expect from the roentgenologist a film that will show not only the fracture line but also the shadows of the grooves of the middle artery, the superior sagittal and lateral sinuses, and the posterior wall of the suspected frontal sinus.

METHOD

One thousand consecutive plain roentgenographic studies for head trauma from January, 1951 through 1955 were reviewed. Almost all of these patients had come directly from the emergency room with a requisition stating that a skull fracture was suspected and asking that a "wet" reading be made.

Unless otherwise specified, roentgenograms in three views were taken, consisting of frontal occipital and stereoscopic lateral views, the latter depending on the side of the trauma.

The clinical records of the patients who had traumatic lesions demonstrated on the plain films were then reviewed.

RESULTS

Of the 1,000 cases reviewed there were 150 cases called positive from the roentgenographic viewpoint. These represented 141 vault fractures of various types, 7 simple fractures of the base, 1 traumatic separation of the right half of the lambdoidal suture in a nine year old boy and 1 separation of the coronal suture in a ten months old male infant. Thus, there were 15 per cent positive traumatic cases as shown by the plain skull films on the initial study or in a few cases by almost immediate follow-up films.

These 150 positive cases were correlated with the clinical findings as follows:

Simple vault fractures without cerebral manifestations	76
Simple base fractures without cerebral manifestations	2
Simple vault fractures with cerebral concussion	47
Simple base fractures with cerebral concussion	5
Simple vault fractures with cerebral laceration	9
Simple vault fractures with subdural hematoma	3
Depressed vault fractures with subdural hematoma	1
Depressed vault fractures without cerebral manifestations	1
Simple vault fractures followed by post-traumatic epilepsy	2
Simple vault fractures with subdural hematoma followed by post-traumatic epilepsy	1
Simple vault fractures with cystic hygroma followed by post-traumatic epilepsy	1
Traumatic separation of the lambdoidal suture without cerebral manifestations	1
Traumatic separation of the coronal suture without cerebral manifestations	1

DISCUSSION

Twenty years ago the treatment of acute head injury was subject to certain ironclad rules. These consisted essentially in immobilizing the patient and following him closely from the clinical and particularly the neurologic standpoint. Certain neurosurgical procedures were sometimes done, especially to control intracranial hemorrhage, to relieve intracranial pressure or to remove foreign bodies from the cranial cavity. The patient was rarely subjected to roentgen examination of the skull during the acute phase of the therapy.

There has been a recent trend to pay greater attention to the value of immediate skull roentgenograms in the treatment of acute head trauma. Some of this trend may reflect the increasing use of diagnostic roentgenography in other fields of medicine, whether warranted or not. The anxiety of the physician and the pressure brought to bear upon him by the family may be a factor. The medicolegal aspect is another factor.

There are at the present time many neurosurgeons who routinely admit their patients with head injuries via the radiologic department provided that certain criteria are met. They feel that routine skull roentgenography is an essential part of the physical examination and that very valuable information can be obtained by this means, assuming that the status of the patient is

not jeopardized. Recent technical advances in roentgenographic apparatus enable the taking of diagnostic films without disturbing the patient appreciably. Even if such apparatus are not available, it is possible to make satisfactory roentgenograms by means of portable Bucky diaphragms or with the newly developed grid front cassette, without necessitating any movement of the patient.

The policy of the neurosurgical service at this institution is to consider skull roentgenography as strictly an adjunct to the clinical follow-up of the patient in head trauma. It is almost never an emergency procedure.

SUMMARY

An attempt has been made to survey the representative literature dealing with the role of immediate plain skull roentgenography in acute head trauma.

One thousand consecutive roentgenograms of the skull, taken for suspected fracture were analyzed statistically. There were 141 vault fractures, 7 basilar fractures and 2 separations of sutures in this group. Of the 150 positive cases there were 69 cases with clinical manifestations due to head trauma, while 81 showed no clinical or laboratory findings of cerebral damage.

Although there is still marked conservatism in respect to the immediate roentgenography of the skull in acute head trauma, there is a definite trend toward change. However, the patients must remain under the supervision of the attending neurosurgeon during this procedure. Routine roentgenography of the patient's skull in suspected head trauma cases should be considered a part of the physical examination and must not precede or substitute the more important clinical evaluation.

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FIBROUS DYSPLASIA OF THE SKULL WITH SARCOMA

A CASE REPORT

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FIBROUS dysplasia does not commonly involve the bones of the cranium or face, and is rarely complicated by malignancy. We know of only 2 other cases in which it appears that medullary replacement tissues characteristic of the disease, have become sarcomatous. Knaggs[4] found myeloid sarcoma in the nasopharynx of a specimen, the Bristol skull, which he included in Group II of his classification. Fairbank[3] cites a case reported by Stock in 1900 in which nasopharyngeal fibrosarcoma complicated leontiasis ossea. Burger and Lehman[1] have found a concurrent, but only incidental Marjolin's ulcer.

Cases of cranial fibrous dysplasia appearing in the medical literature are usually named leontiasis ossea, which is a term descriptive of the appearance of the head and face and has sometimes included recognizable specific diseases such as osteitis deformans, rickets and endocrine disorders.[7] Knaggs' classification is more sharply restricted to include two groups in which tissue changes are similar though not identical. Group I is described as a creeping periostitis of the bones of the face and skull, the cause of which is supposed to be infection of low virulence. Group II is characterized by insular replacement of normal medullary bone with fibrous tissue and calcium spheroids. Confluence of islands may be extensive and there is expansile effect. The roentgenographic appearance is that of bone of heavy, usually even, density. The nasal accessory sinuses tend to become obliterated by accumulation of fibrous tissue and cellular debris. Fibrous tissue may convert to delicate cancellous bone. The case herein reported seems to conform to the description of Knaggs' second group.

Windholz[9] in considering the appellation of leontiasis ossea, recalls that the term was originally used by Virchow and subsequently by Paget and by von Recklinghausen to describe three types of facial appearance bearing some similarity and, respectively, the names of these authors. Windholz regards the first and third types as being examples of cranial fibrous dysplasia, whereas Paget's disease may be differentiated by its distribution, by roentgenographic appearance and often by characteristically abnormal biochemistry.

The cause of cranial fibrous dysplasia has not been determined although a number of etiologic factors have been suggested. Knaggs[4] and Philps[7] cite cases in which infection appears to have been the cause with foci originating in the dental alveolus, the eye, the lacrimal sac or the nasal accessory cavities. Eden[2] advances the hypothesis that trauma may be a factor and observes that the histologic appearance is more nearly that of osteochondroma as found in cartilaginous bone rather than a response to infection.

There is general agreement as to the course of the disease. It begins in adolescence and progresses slowly. It is not incompatible with longevity and may not be disabling. Stenosis of a cranial foramen may cause loss of function of whatever nerve occupies it.[1] Tumefaction may be of such size that its blood supply will not sustain it and central necrosis results,[1] or necrosis may occur when there is a complicating osteitis deformans.[6] It has been observed that the disease is commonly unilateral, and commonly involves frontal bones and those comprising the anterior fossa and the bones of the face. However, it may be more extensive, particularly in the base of the skull.

REPORT OF CASE

A white male patient, forty-eight years old, was admitted to the Deaconess Hospital on August 22, 1951, complaining of a slightly pain-

ful swelling over the right eye which he attributed to trauma incurred three weeks previously. He was concerned because the swelling, instead of diminishing, had increased in extent. There was no complaint of headache or vertigo.

Significant information as to the family history appears to be limited to the circumstance that all of the members of the immediate family have been large people with large hands and feet.

In the patient's personal history there is no account of serious acute illness, serious injury or major surgery. Since adolescence he has been quite large with large hands and feet and a large head with prominent features. When the patient was about twenty years old, he lost useful vision in his right eye, retaining light perception. There is no history of abnormal thirst or appetite or of urinary frequency. He has been a laborer and physically able to perform hard manual labor without undue fatigue.. Because of a grotesque appearance due to his size and facial prominences, he has usually been an object of ridicule by village children, a circumstance not shared by other members of his family.

At admission, his body weight was 275 pounds and his height 76 inches. Temperature, pulse rate and character, respiratory rate and blood pressure were not remarkable. There was marked prominence of the right facial bones including the right half of the mandible. The head was generally large, the anteroposterior diameter being proportionately greater than the transverse diameter. The supra-orbital ridges were prominent and asymmetrical, the teeth extensively carious. There was a rounded firm prominence of the right fronto-malar area about 10 cm. in diameter, 3 cm. in elevation, and fluctuant at the center (Fig. 1). The right eye was amblyopic, proptosed and extruding slightly downward. External genitals were normally developed. The hands and feet were symmetrically quite large and thick. Laboratory procedures including blood chemistries were normal.

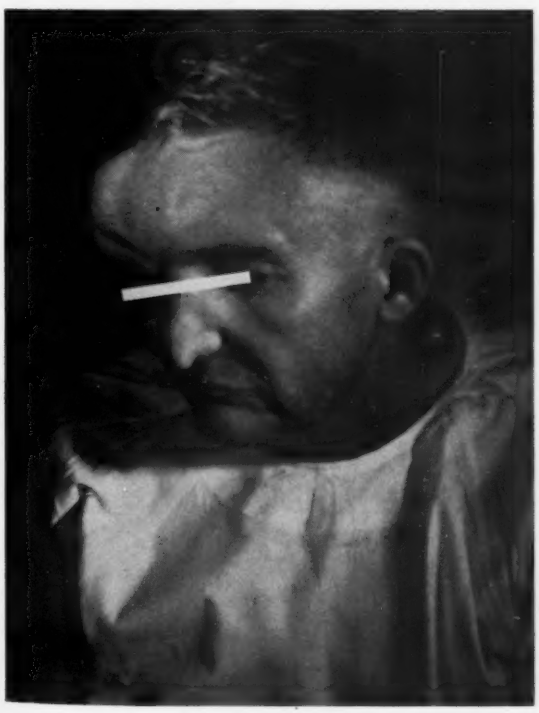

Fig. 1

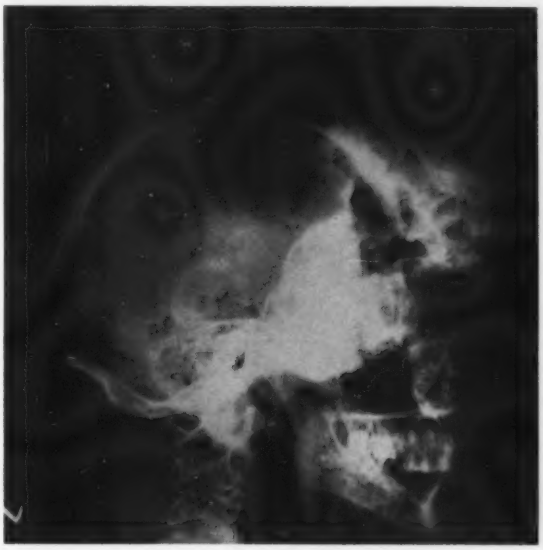

Fig. 2. Left lateral roentgenogram of the skull prior to therapeutic irradiation.

Roentgenographic studies of the skull made on August 22, 1951 (Fig. 2) demonstrate largeness and asymmetry of form and structure. Very heavy bone density was found in the right sphenoid, ethmoid, malar, frontal and maxillary bones and in the right half of the mandible, and moderate thickness of bones elsewhere in the cranial vault and base of both sides. The heavy density in the right anterior fossa was nearly even, but in the right frontal the diploe was quite uneven with an appearance of contained cysts of variable size. The right orbital fissure, as seen projected through the orbit, was sharply contracted; the right maxillary sinus nearly obliterated by denseness of the containing bone. The right side of the face, including the mandi-

FIG. 3. Right lateral roentgenogram of the skull made three months after completion of therapeutic irradiation of the right frontal tumor.

ble, was sharply prominent. The sella turcica, not seen in conventional films, was poorly demonstrated by laminagraphy, and seemed to be neither eroded nor expanded. No structural defect of diagnostic significance was found in the bones of either hand, the lumbar spine or the pelvis. The roentgenographic impression was that of a fibrous dysplasia of the skull, with cystic areas in the right half of the frontal bone. The findings seemed to be not consistent with a diagnosis of Paget's disease. On August 23, 1951, a biopsy was taken from the frontal tumor mass. The microscopic diagnosis was fibrosarcoma.

No surgical intervention appeared feasible and little favorable response was anticipated from therapeutic irradiation. Nevertheless, palliative roentgen therapy was begun on August 25, and continued at a slow rate until October 3, 1951, with factors of 250 kv. peak, 50 cm. distance and 1 mm. of copper filtration. The tumor dose accumulated through one portal was 4,000 r, resulting in excellent reduction in the size of the tumor and causing only mild skin reaction. Relatively asymptomatic, the patient was discharged from the hospital on October 13, but was continued under observation as an out patient. Comparative roentgenograms of the skull were made on November 3, 1951, and on January 4, 1952. In the latter films, the right fronto-malar tumor area had undergone considerable structural change (Fig. 3). The former uneven heavy density of the irradiated area had been replaced by a zone of radiolucence of about 8 cm. diameter, and the limiting tables of the skull and the walls of the adjacent frontal sinus had assumed a sharper definition. No change was found in the uniformly heavy dense bones of the base of the skull.

Final hospitalization was from April 1 to April 22, 1952, for the purpose of receiving transfusion. He had had several severe nasal hemorrhages but was not actively bleeding at the time of admission. He was totally blind and both nares were filled with necrotic tumor to which additional radiation was directed with the hope that an airway might be maintained thereby. Death occurred in a nursing home on May 28, 1952.

At autopsy, it was found that a soft gray tumor mass (Fig. 4) invaded the facial bones extensively, bilaterally breaking through the anterior fossa and the ethmoid to protrude as an occluding mass in the nasopharynx, the oropharynx and the hypopharynx. There were large islands of necrosis. With the exception of a rather minute involvement of the left frontal lobe, there was no invasion of the brain. The pituitary gland although slightly large, was not thought to be abnormal. Microscopically (Fig. 4), sections of cranium with included tumor were similar to the original biopsy except as modified in several areas by irradiation. The pituitary gland was not adenomatous. The anterior part of the right parietal bone and a little of the adjacent frontal bone were grossly thickened but not invaded by tumor, the normal

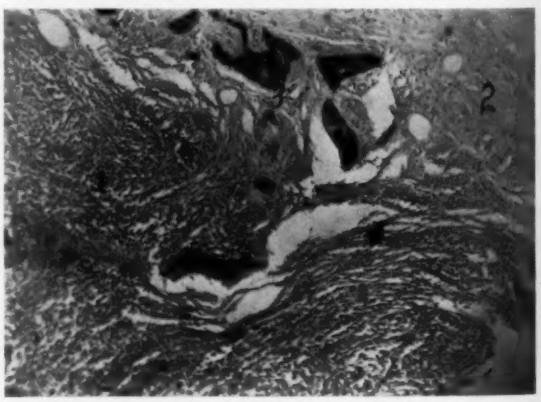

FIG. 4. Microscopic sections obtained from frontal area of the skull at postmortem examination. (1) Fibrosarcoma, (2) benign fibrous dysplasia, (3) degenerative bone.

diploic bone being replaced with fibrous tissue. The postmortem examination was limited to the skull.

DISCUSSION

The antecedent history of the case herein presented appears to conform to the classic descriptions of leontiasis ossea of the type in which unilaterality is usual and fibrous tissue replacement of diploic cancellous bone is the characteristic cytologic manifestation. The only serious physical impairment, blindness of the right eye, is obviously the result of stenosis of the optic canal, and such a cranial nerve lesion is a not unusual consequence of the disease. Gigantism suggested to us some measure of endocrine disorder, so that upon a purely physical basis, we were inclined to make a diagnosis of concurrent acromegaly, which was not actually sustained by the findings at autopsy.

We do not expect fibrosarcoma to be either wildly progressive or particularly radiosensitive, yet the neoplasm that has been described has exhibited those clinical characteristics. Finally, we know of no trend toward malignant degeneration of fibrous dysplasia of the skull; the addition of this case to those of Knaggs and Stock would hardly constitute an incidence of statistical value. The case has been presented as a clinical curiosity.

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GRANULAR CELL TUMOR OF THE NEUROHYPOPHYSIS*

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HERETOFORE, the differential diagnosis of suprasellar neoplastic lesions has included such entities as craniopharyngioma, meningioma, gliomas, cholesteatoma and expanding intrasellar tumors. Certain roentgen criteria have aided in the differentiation of these lesions. Calcification in the suprasellar region is most frequently associated with craniopharyngioma. Hyperostosis of the tuberculum or dorsum sellae is observed in meningioma. The glioma of the optic chiasm is often associated with anterior prolongation of the flattened sella turcica. Cholesteatoma should be strongly considered as a possibility in a young individual when the tumor is not calcified. Supratentorial gliomas, other than that of the optic chiasm, have no particular differentiating features. Recently another entity has been drawn to our attention, namely, granular cell tumor of the hypophyseal stalk.

Harland[3] has described a case of this entity and has emphasized the following points. This tumor is a slowly expanding one which frequently attains a considerable size. Because of its position, the optic nerves are compressed and eventually atrophied. Visual impairment is a predominant symptom. As the duration of the disease lengthens, evidence of increased intracranial pressure appears. Unless some decompressing procedure is done, death ensues. Harland has studied the hypophyseal stalk in autopsy material and has found 2 cases as incidental findings. Hackel[2] in a similar study of routine autopsy material has been able to identify foci of granular cells in the stalk in over 10 cases.

The histogenesis of granular cell tumors has been the subject of considerable study. The prevailing opinion is that it most likely arises from the neural, perineural or endoneural cells. This is of possible importance to the radiotherapist who might be asked to treat this lesion. On the basis of the likely neural origin, one might predict that the lesion most likely would be radioresistant.

This report concerns itself with the second reported case of this entity. It duplicated in nearly every aspect the details elucidated by Harland.

REPORT OF CASE

L.W., a thirty-one year old Negro, was admitted to the medical service of Cleveland City Hospital on December 19, 1951, with a chief complaint of blindness for one month. She first experienced visual difficulties three years prior to admission following a massive postabortal hemorrhage. Her eyesight became progressively worse so that vision had decreased to the

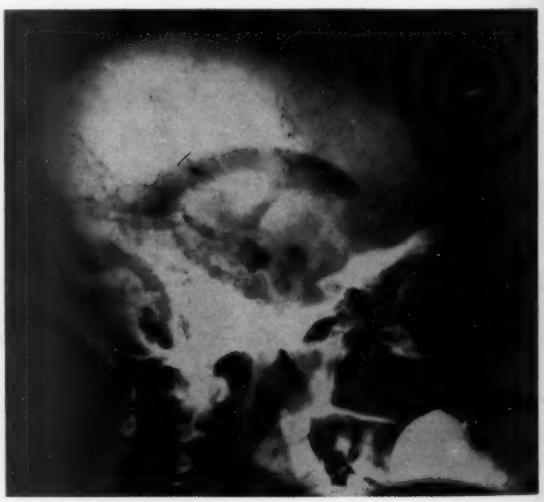

FIG. 1. Pneumoencephalogram shows upward and backward displacement of the floor of the third ventricle.

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point of almost total blindness three months prior to admission. Visual fields were not obtained.

Physical examination disclosed as the sole abnormality bilateral optic atrophy.

Laboratory examination revealed the following serological findings: Kline 2 plus, Wassermann negative. Spinal fluid examination showed the Wassermann test to be negative.

Course in hospital: The neurologist believed that the patient had central nervous system syphilis and recommended that she receive fever therapy with killed thyphoid bacilli. Skull roentgenograms demonstrated erosion of the dorsum sellae and posterior clinoids. Pneumoencephalography was done and revealed elevation of the floors of the third ventricle and the right lateral ventricle. Despite the lack of calcification, craniopharnygioma was thought to be the most likely diagnosis. (Fig. 1, 2, and 3).

The patient was operated upon and the tumor was partially excised. The pathologic diagnosis was granular cell tumor of the neurohypophysis.

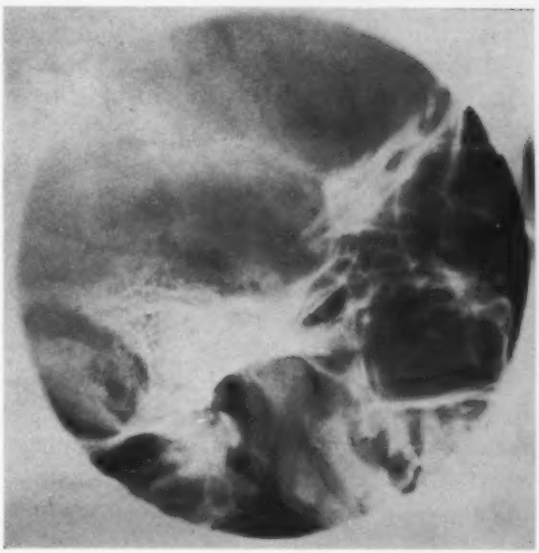

Fig. 3. Coned-down lateral view of the sella turcica shows erosion of the dorsum sellae and posterior clinoid processes.

Fig. 2. Pneumoencephalogram shows upward displacement of the anterior portion of the third ventricle, as well as upward displacement of the floor of the right lateral ventricle.

High voltage (200 kv., half-value layer 1 mm. Cu) roentgen therapy was given. A six field technique employing two temporal, two parietal, a frontal and occipital fields was selected centering on the sellar region. Two fields were treated daily with a dose of 200 r (air) to each. The rotation of fields consisted of left temporal and parietal, frontal and right temporal, right parietal and occipital. The contemplated therapy was to deliver 4,500 r (tumor dose) in four weeks. On the tenth treatment day, the patient noted that her headache had diminished in intensity. The improvement was shortlived as she began to convulse and treatment had to be terminated after approximately 3,200 r (tumor dose) had been given. The patient ran a downhill course, went into coma and died on July 12, 1952. Autopsy confirmed the diagnosis of granular cell tumor of the neurohypophysis. There was no evidence of radiation effect.

DISCUSSION

From a roentgenologic diagnostic viewpoint, there are no features to distinguish granular cell tumors from other suprasellar lesions. In neither of the 2 cases so far described has calcification of the tumor occurred. Only with the report of additional

cases will this observation be validated, and then possibly attain some significance. At this time, this entity should be considered in the differential diagnosis of non-calcifying suprasellar lesions. As far as radiation therapy is concerned, we can only say that in this patient 3,200 r (tumor dose) delivered in three weeks failed to have any effect on the tumor as noted at autopsy.

SUMMARY

1. A case of granular cell tumor of the neurohypophysis has been presented. No distinctive diagnostic features have been observed, but the importance of considering it in the differential diagnosis of non-calcifying suprasellar lesions has been suggested.

2. Radiation therapy consisting of 3,200 r (tumor dose) in three weeks had no effect on the tumor.

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Vol. 76, No. 2

THE TYMPANIC CAVITY AND AUDITORY OSSICLES

ROENTGEN FINDINGS IN HEALTH AND DISEASE

By EUGENE P. PENDERGRASS, M.D., PHILIP J. HODES, M.D., RODERICK L. TONDREAU, M.D., *and* PHILIP A. MARDEN, M.D.

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IN ALL diagnostic roentgenology no other region poses problems so complex as those which concern the tympanic cavity. Unique in many respects, its very roentgen demonstration is a challenge. Indeed, the ability to demonstrate roentgenographically the otic capsule and its contents serves as an index of roentgenographic quality.

The purpose of this report is to demonstrate roentgenographically the tympanic cavity and its ossicles in health and disease. Stimulated by Samuel,[30] we have learned to recognize some of the abnormalities to which this area is host. Whereas often the findings are of modest practical clinical importance, there are times when the roentgen findings prove extremely helpful to the otologist.

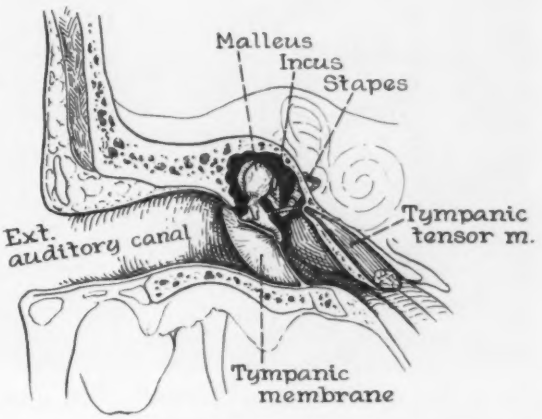

FIG. 1. Diagrammatic illustration of the external ear and the middle ear demonstrating the relationship of the epitympanic recess to the tympanic membrane. Note the tilt of the long axis of the tympanic cavity and its relationship to the tilt of the tympanic membrane.

ANATOMY

Tympanic Cavity. It is not within the province of this report to describe in detail the anatomy of the tympanic cavity and its contents. Only those structures will be discussed which can be seen roentgenographically.

The tympanic cavity is a roughly cylindrical air space in the temporal bone consisting of the middle ear and the epitympanic recess (Fig. 1). Lying at an angle of approximately 20 degrees with reference to the long axis of the body, it measures from 6 to 9 mm. in width and from 12 to 15 mm. in height.[33]

Enclosing the lateral aspect of the middle ear is the tympanic membrane. Through it are visualized the handle of the malleus and the long process of the incus. The bulky head of the malleus and the body of the incus lie above it in the epitympanic recess. Because the tympanic cavity and the tympanic membrane are tilted in the same direction, the epitympanic recess and its contents usually lie immediately above, or even lateral to, the ear drum (Fig. 1).

The medial wall of the tympanic cavity is formed by the lateral wall of the inner ear. Posteriorly it communicates with the mastoid antrum. Anteriorly lie the eustachian canal and a channel in which is found the tensor tympanic muscle. A hard plate of bone, the tegmen tympani, forms its roof; below is the jugular fossa.

Within the tympanic cavity are contained the auditory ossicles, nerves, blood vessels and ligaments, all of which are covered by a thin mucous membrane.

Ossicles. Most laterally placed of the three auditory ossicles is the malleus (Fig. 1 and 2). Medial to the malleus and inti-

From the Departments of Radiology and Otology, Hospital of the University of Pennsylvania, Philadelphia, Pennsylvania. Presented at the Fifty-sixth Annual Meeting of the American Roentgen Ray Society, Chicago, Illinois, September 20–23, 1955.

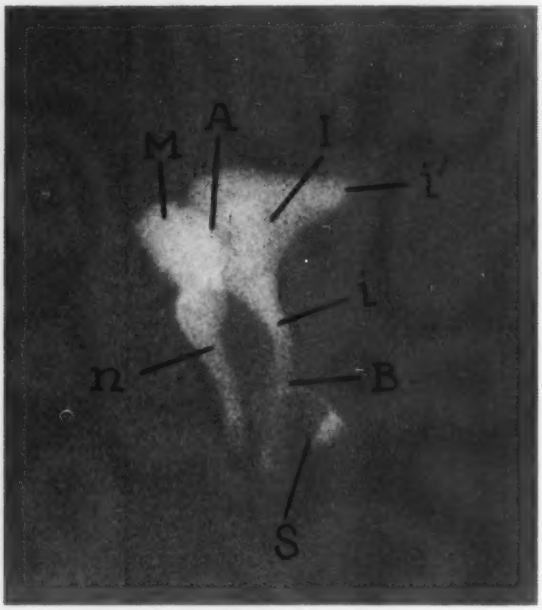

Fig. 2. The ossicles of the middle ear magnified approximately six times. (*M*) malleus; (*n*) long handle of the malleus; (*I*) incus; (*i*) long process of the incus; (*i'*) short process of the incus; (*S*) stapes. The incudomalleolar joint lies at *A*; the joint between the stapes and incus lies at *B*.

mately joined with it is the largest of the three ossicles, the incus. The third ossicle, the stapes, lies medial to the incus to which it is fastened at one end.[25]

The malleus, named also the malleolus or hammer, is composed chiefly of a bulky club-like mass, the head, and much thinner handle-like piece of bone, the manubrium. The head articulates intimately with the incus in the epitympanic recess (Fig. 2); the manubrium is attached to the ear drum.

The incus, called also the anvil, is somewhat triangular in shape with a long thin process of bone extending downward from the body toward the stapes. The base of the triangle forms the incudomalleolar joint (Fig. 2); its apex, the short process, is attached to the posterior portion of the epitympanic recess. The long thin process runs almost parallel to the handle of the malleus turning medially at its tip to articulate with the stapes.

The stapes, so named for its resemblance to a stirrup, is the smallest auditory ossicle. Its head articulates with the long process of the incus; its foot-plate is attached to the vestibular window of the inner ear.[4,5,6,29]

The auditory ossicles are connected to each other by minute diarthrodial joints, each provided with its own capsule and synovial membrane.[10,13] Suspended within the tympanic cavity and epitympanic recess by tiny ligaments and muscles, the bony chain is fixed at one end by the tympanic membrane and at the other end by the bony labyrinth.[20] So designed are these structures that movements of the tympanic membrane are transmitted in piston-like manner to the foot-plate of the stapes at an average transmission ratio of about fifteen or twenty to one.[33] The necessity for such a system is evident when one compares the impedance of the very light compressible medium, air, to the almost incompressible cochlear fluid. This system of levers makes it possible to transform large displacements of air into small displacements of fluid while transforming, coincidentally, the small forces acting upon the ear drum into the large forces acting upon the cochlear fluid which bathes the auditory nerve endings.[33]

Eustachian Canal (*pharyngo-tympanic tube*, *auditory tube*.)*[25] The eustachian canal, called also the pharyngo-tympanic tube or auditory tube, originates in the medial and anterior aspect of the middle ear. Its tympanic portion enclosed in the temporal bone is short, rigid, and nearly circular in contour. Its lumen, 3 to 6 mm. in diameter, is permanently open. In length the tympanic portion represents approximately one-third of the total length of the eustachian canal.[25]

* Bartolomeo Eustacchio (Eustachius 1520–1574[12]) in an epistle on the organs of hearing which he dedicated to the Bishop of Milan in 1562 said, "To be sure Galen has no where so far as I know mentioned these bones which are the smallest of all and yet they are not, as some write, to be neglected because of their tininess, since their usefulness is not small and their craftsmanship proves the great wisdom of the Creator in shaping them; . . . these two ossicles were first pointed out by Alexander Achillinus the eminent philosopher of Bonn (Alessandro Achillini, Italy 1463–1512) and Jacob of Capri."

Quoting further from this same epistle Eustachius went on to describe the canal which bears his name as coming "from the cavity of the petrous bone—begins like a small canal, as wide as a slender reed, which proceeding obliquely to the anterior and interior of the base of the skull penetrates and perforates the whole bone ending in the middle of four foramina . . . ."

The longer and wider portion of the eustachian canal, that portion imbedded within the pharynx, is flexible, slit-like and able to collapse. Communicating with the nasal cavity it serves to equalize air pressures within the tympanic cavity with external atmospheric pressures. Activated normally by swallowing, yawning, or blowing the nose, the tube is opened automatically by the muscles which control it. Were it not for this free communication of air there would develop within the tympanic cavity a negative pressure which would interfere with satisfactory working of the auditory transmission apparatus.[1,2,20] Its other functions include draining fluid from the middle ear and closing off the tympanic cavity from the pharynx preventing autophony, in which one's own respiratory sounds and voice are heard loudly in the affected ear due to a persistently open eustachian canal.[18,21,34]

In infants the eustachian canal is shorter, wider, and straighter than in adults. These anatomic differences explain the relative ease with which children develop middle ear infections.

ROENTGEN ANATOMY

The tympanic cavity is seen best in roentgenograms of the base of the skull (submento-vertical, Hirtz) (Fig. 3). The most brilliant exposures are obtained by focusing very small cones over each mastoid individually; in practice routine exposures of the base of the skull are of sufficient density and contrast to demonstrate the tympanic cavity adequately. In part this is due to the inclination and direction of the tympanic cavity which in the Hirtz projection permits its longest axis (longest column of air) to lie along the course of the incident rays.

Usually the tympanic cavity appears immediately behind and medial to the condyle of the mandible (Fig. 3 and 4). Measuring approximately 1 cm. in diameter its periphery is sharply demarcated and almost circular in configuration. To some degree visualization of the tympanic cavity

FIG. 3. Normal. Submento-vertical view of the tympanic cavity (*T*) and eustachian canal (*E*). The external auditory canal is clearly visualized at the arrows. The combined shadow of the malleus and incus is seen at *O*.

is dependent upon the density of the adjoining structures. In highly pneumatized mastoids contrast of the air filled tympanum is less striking than in diploic or sclerotic mastoids.[29]

Of interest in submento-vertical exposures is the anatomic relationship of the tympanic cavity to its tympanic membrane. Easily demonstrated with contrast media the shadow of the sloping tympanic membrane almost always may be found superimposed upon the radiolucent image of the tympanic cavity (Fig. 5). In rare instances the image of a thickened ear drum itself may be identified as a fan-like area of increased density which is superimposed upon the lateral aspect of the air-filled middle ear (Fig. 18).

Roentgen visualization of the auditory ossicles as a group is not difficult. To identify each ossicle individually, however, is difficult for the malleus and incus measure but 5 to 9 mm. in their longest dimension while the stapes measure but 3 mm.

As a unit the ossicles are demonstrated easiest in the base view of the skull (Hirtz; Fig. 3 and 4). Situated within the air-filled tympanic cavity the composite shadow of the head of the malleus and the body of the incus may be identified as a bulbous punctate density 2 to 3 mm. in diameter. The relationship of this punctate density to the

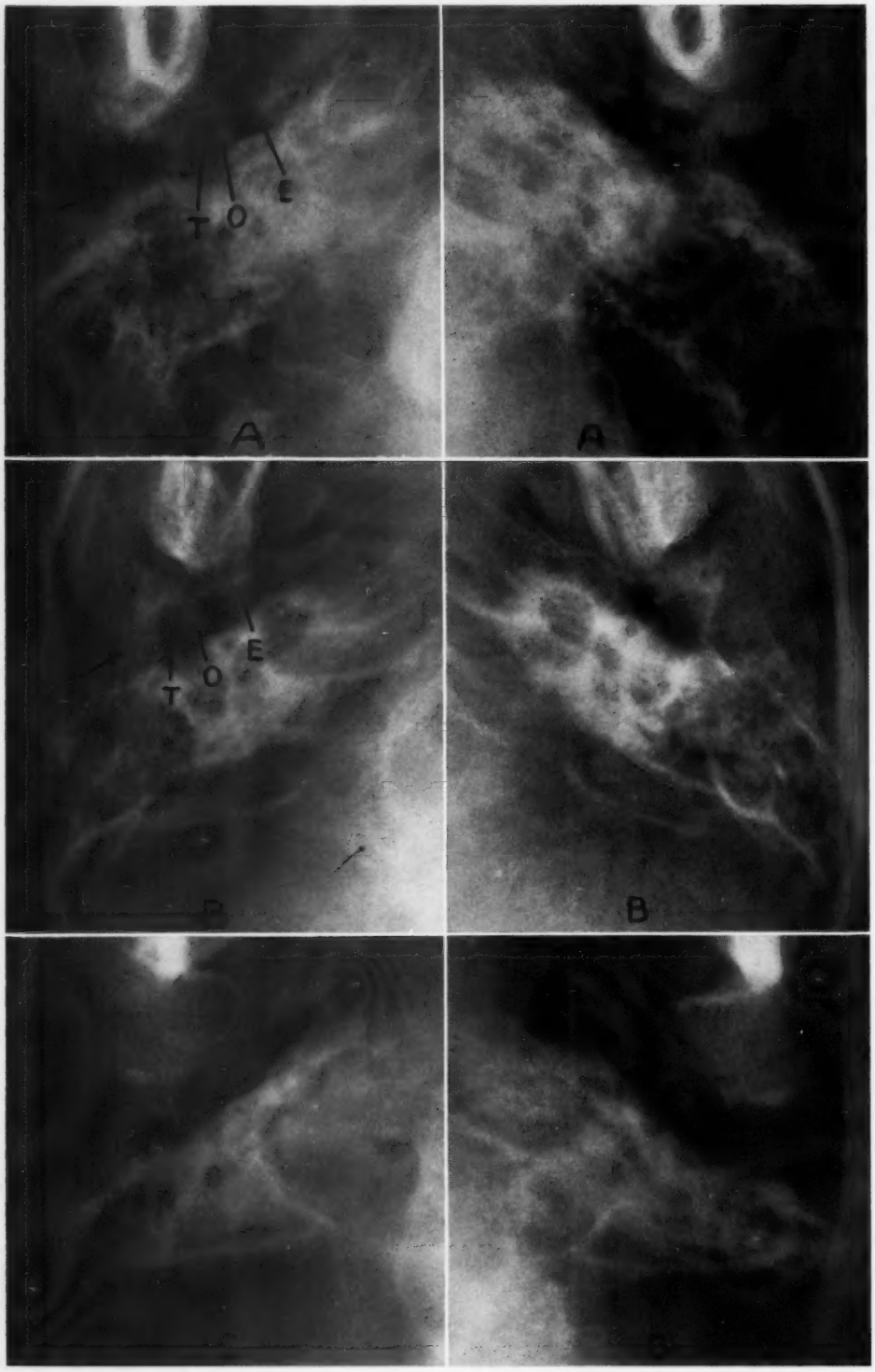

Fig. 4. Normal. Submento-vertical projection. Three healthy individuals (*A*, *B* and *C*) reveal the roentgen anatomy of the ear. The tympanic cavities (*T*) are all clearly defined and radiolucent. The eustachian canals (*E*) are seen with ease. The ossicles (*O*) are represented by their composite shadow at the incudo-malleolar articulation. The arrows point to the external auditory canal.

bony wall of the tympanic cavity varies with projection. Seen best in the center of the middle ear, it may occupy a forward position or be superimposed upon the internal ear posteriorly. In this projection the handle of the malleus and the long process of the incus may be identified radiating like the hands of a clock from the bulbous shadow marking the incudomalleolar joint. Their density is about equal. On occasions one may demonstrate even the stapes but this is rare.

Routine lateral exposures of the mastoids do not demonstrate the tympanic cavity. In these projections the rays pass through the narrowest portion of the middle ear cleft where little contrasting air exists. By tilting the head into an axial projection the middle ear can be visualized roentgenographically in the quasi-lateral view. The classical axial view described by Mayer[23] and its less elongated version described by Owen[24] (Fig. 6) both demonstrate well this portion of the temporal bone. Here the body of the malleus occupies an anterior position with a portion of its rounded head superimposed upon the anterior wall of the auditory canal. The head of the malleus is also superimposed upon the epitympanic recess. From it, running downward across the auditory canal, is the long handle of the malleus which is attached to the ear drum.

Intimately connected with the rounded shadow of the head of the malleus in the epitympanic recess, and extending backward from it, is the somewhat triangular shaped body of the incus (Fig. 2 and 6). Occasionally the apex of this triangular density, the short process of the incus, may be identified as it is directed somewhat horizontally posteriorly toward the back of the epitympanic recess. The long process of the incus may also be seen within the auditory canal as it descends from the region of the body of the incus in a direction somewhat behind and parallel to the manubrium of the malleus.

The stapes cannot be demonstrated in the axial projection. In rare instances the stapes will be recognized in the submentovertical projection.

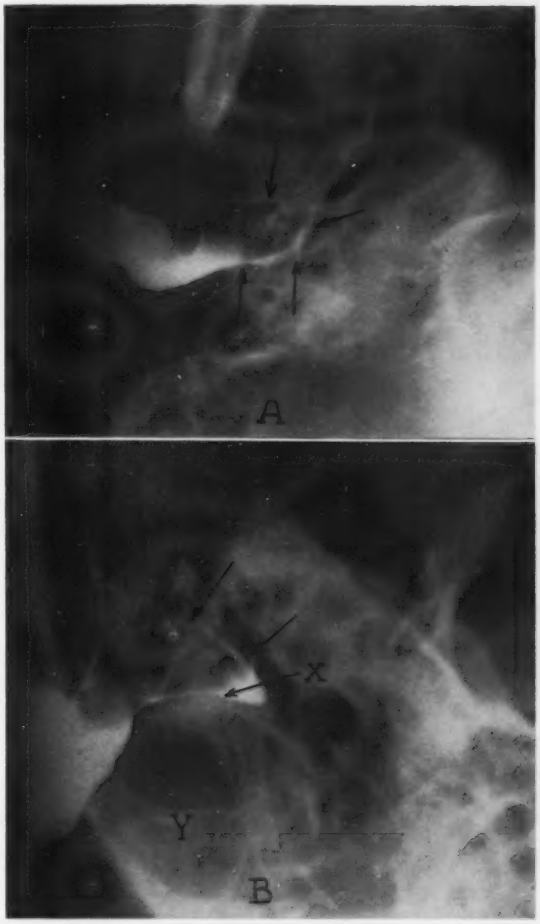

Fig. 5. The medial aspect of the external auditory canal has been opacified using pantopaque. In the Hirtz projection (*A*), the arrows reveal the outline of the tympanic cavity. Also indicated by the arrows is a slight amount of opaque medium outlining the most medial aspect of the external auditory canal. Note that the tympanic membrane is superimposed directly upon the shadow of the tympanic cavity. In the Chamberlain-Towne projection (*B*), the medial aspect of the external auditory canal is also identified using opaque medium. The arrows indicate the most medial portion of the external auditory canal revealing, thereby, the slope of the tympanic membrane. Note the relationship of the anterior wall of the external auditory canal at *x* with reference to the condyle of the mandible at *y*.

Usually there exists no difference in density between the malleus and incus. At the incudomalleolar joint they are indistinguishable roentgenographically.

Fig. 6. Owen projection revealing the malleus and incus within the air-filled shadow of the external auditory canal. Inserted is a reproduction of an actual anatomic specimen (*X*) photographed in a projection similar to the Owen projection. The head of the malleus is seen at *M*; the manubrium of the malleus is seen at *m*; the body of the incus lies at *I*; the arrows point to the anterior wall of the lateral sinus. (Courtesy of Dr. G. R. Owen, Los Angeles, California.)

EUSTACHIAN CANAL

Roentgenologically the bony portion of the eustachian canal can be demonstrated with ease in the submento-vertical projection.[14,29] Extending medially and forward from the inner and anterior quadrant of the tympanic cavity the air-filled canal appears delicate and spearlike as it courses along a line immediately medial to the foramen spinosum toward the optic canal (Fig. 3, 4 and 7).

The earliest attempts to visualize the eustachian canal roentgenographically employed contrast media.[11,15,26,31] In most instances the opaque media were injected in retrograde fashion through the nasopharyngeal end of the eustachian canal by means of catheters. We have demonstrated the eustachian tube (Fig. 7) in patients with chronic draining ears by injecting pantopaque into the external auditory meatus, taking advantage of the hole in the tympanic membrane. By plugging the ear with the shoulders of the syringe, aspirating, and then injecting slowly, we have been able to demonstrate configuration and course of the canal with little difficulty (Fig. 7).

CONGENITAL VARIANTS

The term "congenital atresia of the ear" has been accepted to include a host of congenital anomalies that affect the derivatives of the posterior end of the first and second branchial clefts.[2,32] Most common are the abnormalities of the external ear. Occurring about once in every 2,000 aural patients, the external auditory canal may

Fig. 7. Submento-vertical projection. Course of the eustachian canal (*E*) has been identified by opaque medium injected through the perforated tympanic membrane. The tympanic cavity is seen at *T*.

be hypoplastic, partially obliterated, or entirely absent. In almost 15 per cent the process is bilateral. Usually complete atresia is formed by a plate of bone thought to be derived from the proximal portion of the hyoid bone. No sexual or hereditary predominance has been established.

Noteworthy are the racial differences in the external auditory canal. Diffuse hyperostosis resulting in remarkable narrowing, with or without focal exostosis (Fig. 8) is particularly frequent among old aborigine groups of North America, Polynesia, and some parts of Mexico and South America.[3]

Commonly associated with atresia of the external auditory canal are homolateral anomalies of the auricle, face, and skull. Usually the tympanic cavity is similarly affected.[28,29,32] Changes in the malleus and incus are common; they may be abnormally formed, irregularly aligned or fused.[2] The stapes and eustachian canal as a rule, are normal, or but minimally affected.[32] The mastoid is normal or overdeveloped.[2]

The internal ear rarely participates in these anomalies, being derived from structures that mature much earlier during fetal life than the external ear (Fig. 9).

The roentgen manifestations of congenital atresia of the external ear are dependent

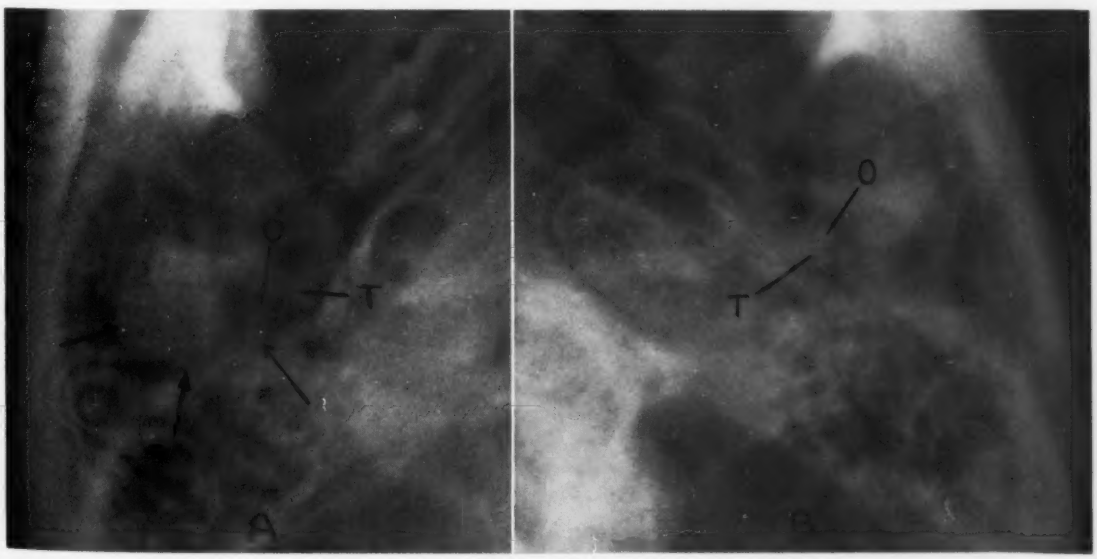

Fig. 8. Osteoma of the external auditory canal. Submento-vertical projection. The arrows outline a large osteoma springing from the anterior wall of the external auditory canal in *A*. The tympanic cavities (*T*) in both ears (*A* and *B*) are normal; the ossicles (*O*) in both ears are clearly defined.

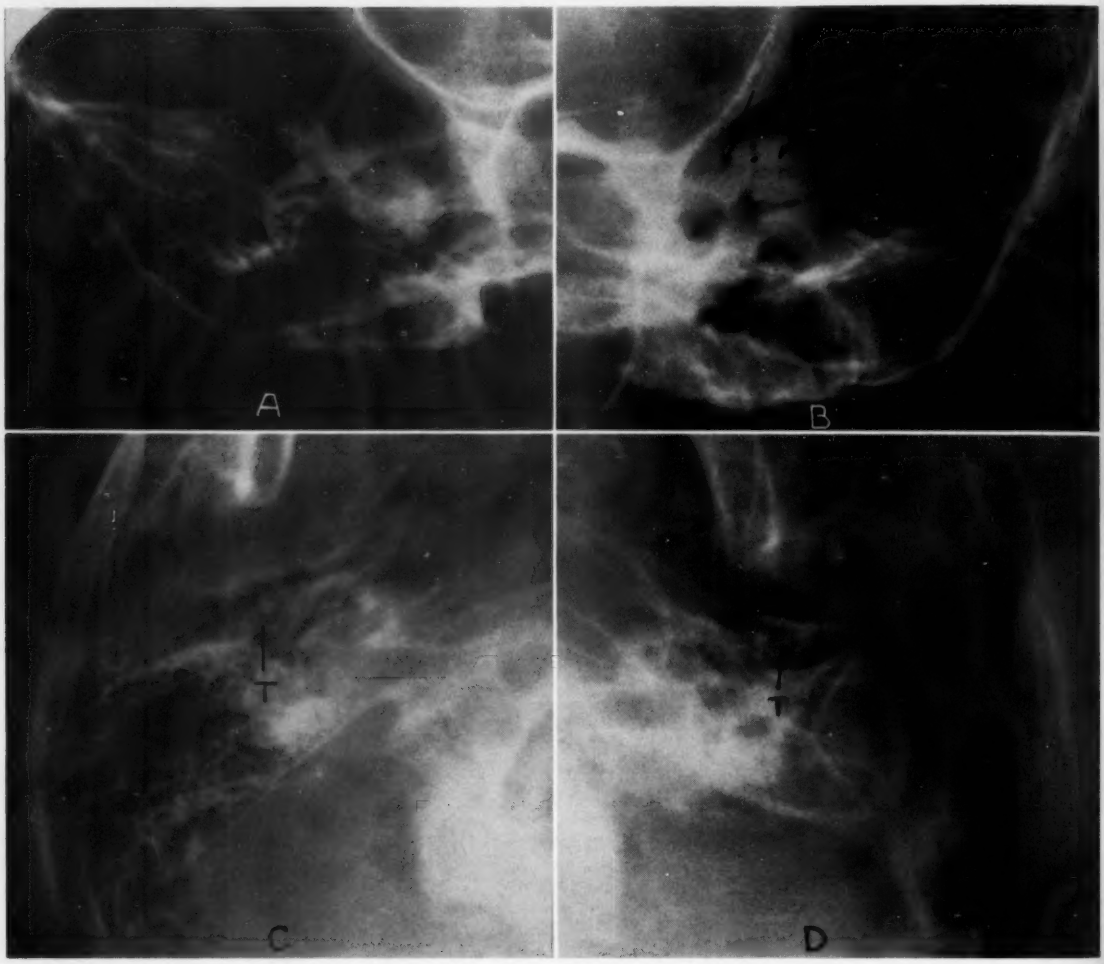

Fig. 9. Unilateral congenital atresia. (*A* and *B*) Stenvers projection; (*C* and *D*) submento-vertical projection. A male, nine years of age, presented a deformity of the auricle of the left ear which was associated with complete atresia of the left external auditory canal. The right ear was normal. The normal right ear is represented in *A* and *C*. The abnormal left ear (*B* and *D*) reveals marked depression of the tegmen tympani in the Stenvers projection (*B*) due to lack of development of the mastoid. Attention is called to the normal appearance of the internal ear in *B*, indicated by the arrows.

upon the presence of air in the auditory canal. When the atresia is incomplete contrasting air often depicts the character of the anomaly in routine lateral, axial, or submento-vertical views. Contrast media are particularly useful in such instances (Fig. 10). When the atresia is complete, however, the problem is far more difficult. Stereoscopic submento-vertical exposures sometimes help; laminagrams made in various planes with reference to the long axis of the temporal bone are extremely valuable. By sectioning the temporal bone in two planes at right angles to each other according to the method of Camp and Allen[8] the nature and extent of the bony atresia can be estimated. Occasionally the direction of tube travel must be altered with reference to the long axis of the body before informative laminagrams are obtained. In some the direction of tube travel must be parallel to the long axis of the body; in others it must be perpendicular to the long axis of the body.

Changes in the tympanic cavity are not difficult to recognize in congenital atresia

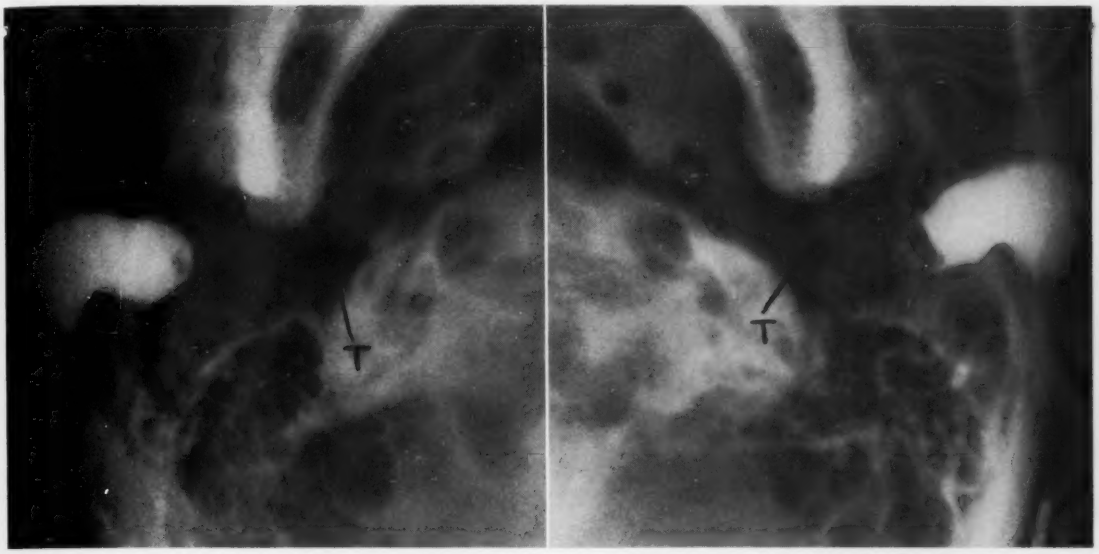

FIG. 10. Bilateral congenital atresia. Submento-vertical projection. A male, fourteen years of age, revealed complete atresia of both external auditory canals since birth. All his life he had been hard of hearing. Only the membranous portions of both external auditory canals are identified with the opaque solution. Almost 1 cm. separates the region of the tympanic cavity (*T*) from the site of the auditory atresia. Both tympanic cavities (*T*) are irregular and asymmetrical. There is no semblance of a normal ossicular shadow in either tympanic cavity.

when the abnormality is unilateral. The ipsilateral cavity usually is not as large as the normal; nor is it as clearly demarcated (Fig. 11 and 12). Its shape, too, may vary from the normal.

As the tympanic cavity varies in congenital atresia, so too will its auditory ossicles vary. Sometimes the ossicles appear normal roentgenographically; more often they appear totally irregular and abnor-

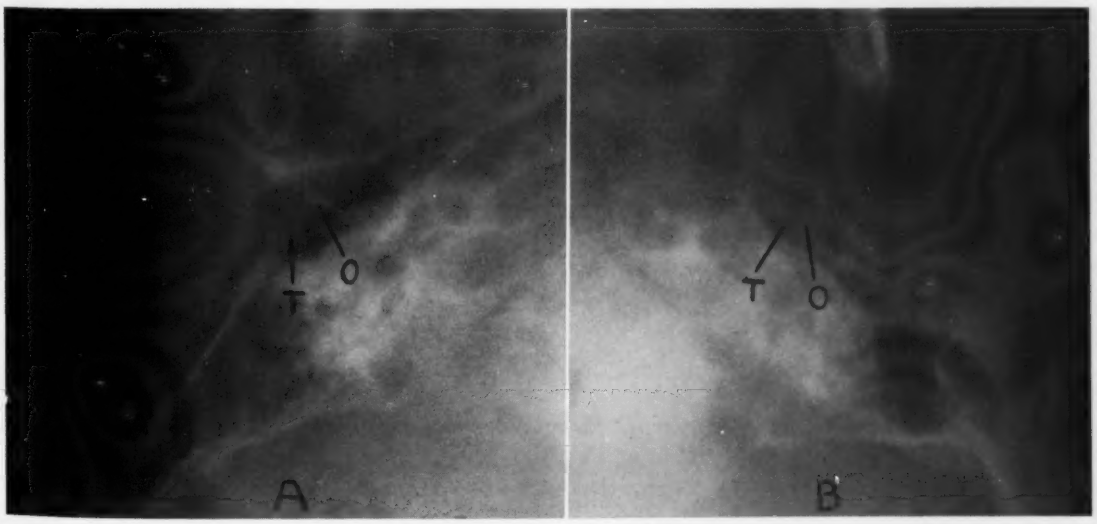

FIG. 11. Unilateral congenital atresia. Submento-vertical projection. A child, three years of age, revealed complete atresia of the left external auditory canal where only a slight dimple marked its site. The right ear was normal. The roentgen examination of the right ear (*A*) reveals no abnormalities. The abnormal left ear (*B*) reveals a small tympanic cavity (*T*) which is elliptical. Whereas one suspects that the ossicles lie at *O*, one cannot be sure that these densities really represent the ossicles.

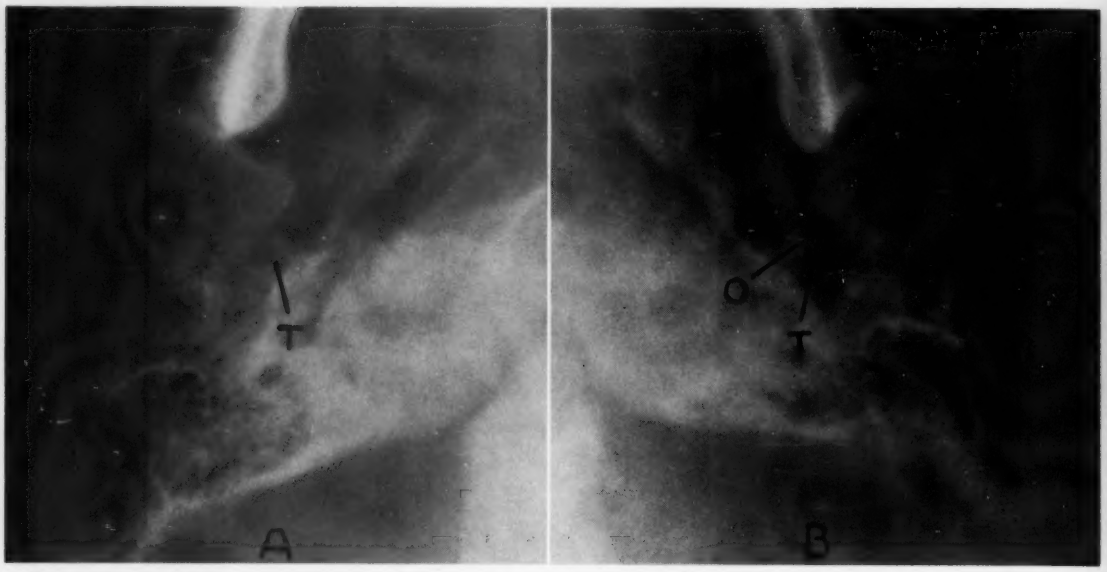

Fig. 12. Bilateral congenital atresia. Submento-vertical projection. A female, thirty-four years of age, knew that both external auditory canals were very narrow since birth. All her life she had been hard of hearing, the right ear being worse than the left. Physical examination revealed marked atresia of both external auditory canals; neither tympanic membrane could be seen. The right ear (*A*) revealed no evidence of a bony external auditory canal. The tympanic cavity (*T*) is small. No ossicles can be demonstrated. The left ear (*B*) revealed clearly its tympanic cavity (*T*). The ossicles (*O*) seem normal. Note how extensive is the pneumatization of the right mastoid (*A*) compared to the left (*B*). This may account for the lack of visualization of the tympanic cavity.

mally placed (Fig. 11 and 12). The importance of this information to the otologist cannot be overemphasized. In many instances it determines his course of treatment. As indicated above only the malleus and incus participate in these congenital variants; the stapes and the eustachian canal commonly are normal.

Occasionally the position of the condyle of the mandible is affected in congenital atresia. Instead of being symmetrically placed with reference to the normal side, the condyle may be placed more posteriorly, reflecting the impaired development of the bone in the anterior wall of the external auditory canal.

Auditory atresia may also be acquired. Trauma[9] and infection are its most common causes. Trauma due to gunshot injuries and infections due to middle ear or external ear disease may cause complete or incomplete stenosis. Their roentgen manifestations should be easy to demonstrate, particularly when air or other contrast media can be used.

INFECTIONS

Middle ear infections usually spread from the nasal pharynx to the tympanic cavity by way of the eustachian canal. Far less common are the infections that reach it via the external auditory canal through defects in the tympanic membrane. Whatever the mode of entry, the mucous membranes of the tympanic cavity and its recesses respond to the infection with vascular engorgement, edema, cellular infiltration and exudation. Within hours or days, depending upon treatment, immunity, and virulence of the organism, air-filled chambers of the ear become flooded with exudate.[16]

Roentgenologically this series of events is reflected in a progressive decreased radiolucency in all air-filled portions of the temporal bone. The eustachian canal early loses its spear-like radiolucent quality becoming more radiopaque and less clearly defined (Fig. 13). Eventually the bony canal alone marks its location. At the same time the tympanic cavity becomes progres-

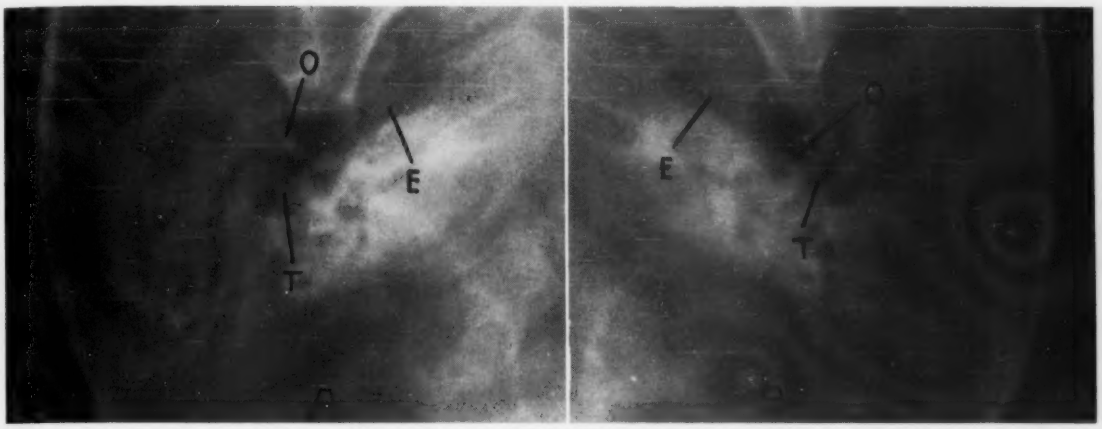

FIG. 13. Acute otitis media. Submento-vertical projection. In the infected ear (*A*) the eustachian canal (*E*) is almost entirely obliterated compared with the healthy ear (*B*). The tympanic cavity (*T*) in the diseased ear (*A*) is a little less radiolucent than the normal. The ossicles (*O*) are not affected.

sively less radiolucent (Fig. 13, 14 and 15). Soon thereafter decreased radiolucency may be identified in the region of the mastoid antrum from where the change gradually extends throughout the entire cellular portion of the temporal bone from mastoid tip to petrosal apex.

Submento-vertical roentgenograms reveal best the changes in the tympanic cavity and eustachian canal.[14] The healthy ear serves as the control with which changes in translucency may be compared. The problem is more taxing when both ears are similarly involved or asymmetrically developed.

Usually the composite shadow of the ossicles is not affected in acute infections. Later, changes in density may be observed

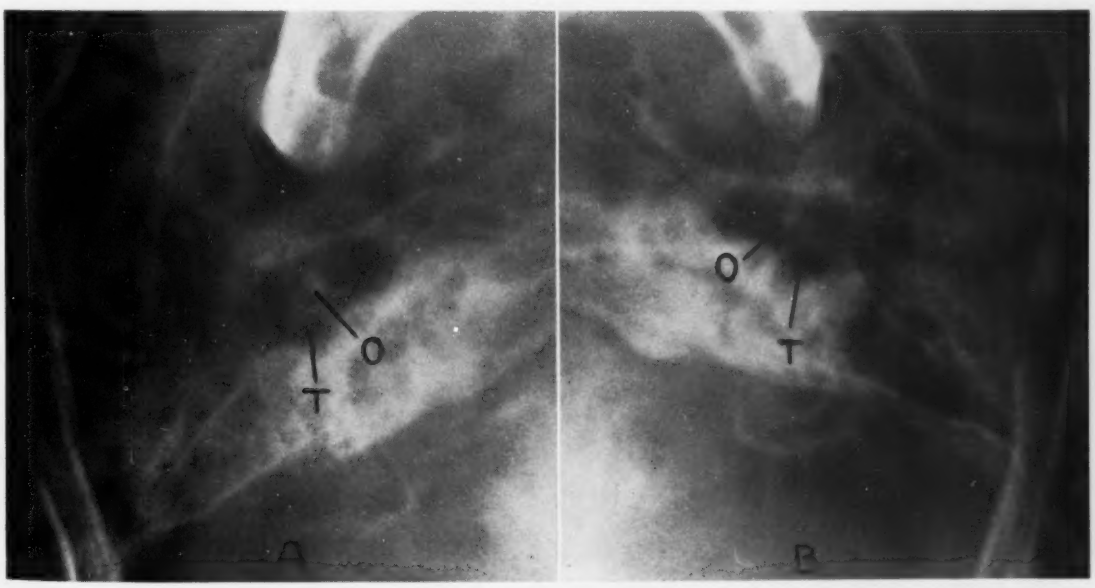

FIG. 14. Acute otitis media. Submento-vertical projection. A two year old male was admitted complaining of pain in the right ear on three occasions during the previous three weeks. On each occasion the patient was treated with antibiotics and improved. Physical examination on the day of this roentgen study revealed bulging and hyperemia of the tympanic membrane on the right side. Moderate tenderness was noted over the mastoid. The left ear was healthy. In the infected ear (*A*) the tympanic cavity (*T*) is far less pneumatized than its normal counterpart in the healthy ear (*B*). The ossicles (*O*) are not affected.

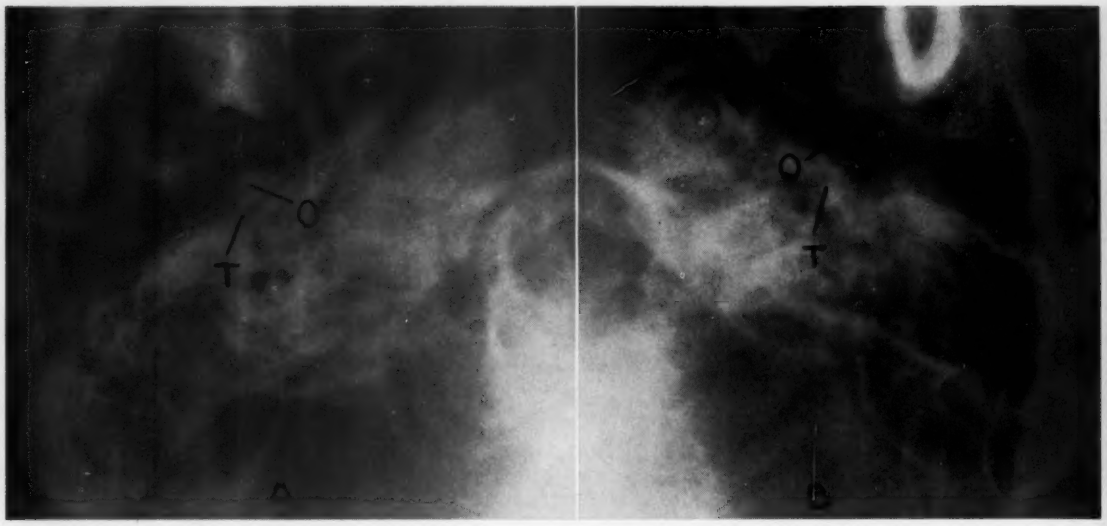

Fig. 15. Subacute otitis media. Submento-vertical projection. A female, thirty-four years of age, complained of intermittent pain in the right ear and mastoid of two months' duration. Two weeks prior to this examination the right ear began to drain a purulent discharge. Physical examination revealed redness, tenderness and swelling in the region of the right mastoid. Pus was found in its external auditory canal. The left ear was normal. The abnormal right ear (*A*) reveals less air in its tympanic cavity (*T*) than in the normal ear (*B*). The ossicles (*O*) seemed irregularly placed in the affected ear.

in the malleus and incus as they become infected themselves or lose their blood supply. The incus undergoes avascular necrosis[14] more commonly than the malleus, which receives its blood supply directly from the tympanic membrane (Fig. 15 and 16).

In chronic otitis media changes in the

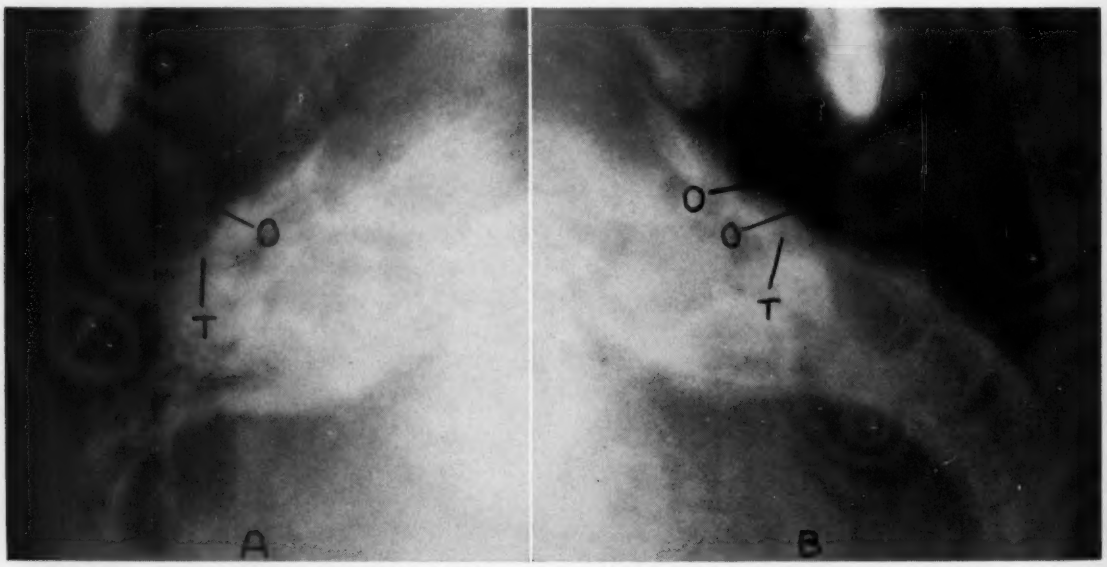

Fig. 16. Chronic otitis media. Submento-vertical projection. A thirty-five year old male was admitted complaining of a purulent discharge from the left ear of thirty years' duration. The right ear was normal. No abnormalities are noted in the right ear (*A*). The diseased left ear (*B*) reveals unusual radiolucency in the region of the tympanic cavity (*T*). This radiolucency is due to bone absorption. Seen with difficulty within the affected tympanic cavity are two totally irregular densities which could represent the ossicles (*O*). At operation the erosion in the tympanic cavity was identified. The malleus and incus were eroded and totally abnormal in configuration.

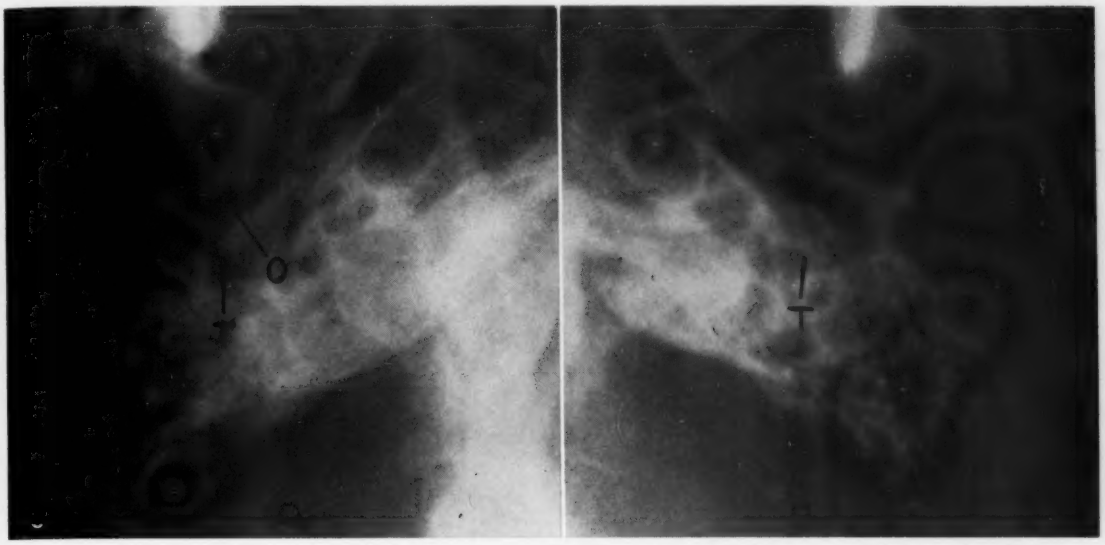

Fig. 17. Chronic otitis media. Submento-vertical projection. A female, eighteen years of age, complained of a chronic discharging ear of seven years' duration. A simple mastoidectomy had been performed several years previously but the drainage continued. There were no complaints referable to the left ear. The abnormal right ear (*A*) reveals clearly its tympanic cavity (*T*). The cavity seems unusually large and its bony margins are eburnated. The ossicles (*O*) are totally irregular in configuration. In the healthy left ear (*B*) the tympanic cavity is not clearly visualized. It seems superimposed upon the internal ear. Unusual pneumatization of the mastoid probably contributes to the difficulty in visualizing this middle ear.

tympanic cavity are the rule. Usually the cavity contains less air and is less radiolucent than the normal (Fig. 17 and 18). It may appear hazy or even clouded in the Hirtz projection reflecting the mucosal thickening, exudation, and condensing osteitis to which it is host. The ossicles, too, are altered in these individuals being sometimes larger in size, often deossified, and commonly less distinct. Not infrequently portions of the bulbous composite shadow of the malleus and incus appear totally irregular or even missing. This is particularly true in the presence of cholesteatomas, when part or all of the ossicular chain may slough (Fig. 19 and 20).

TRAUMA

Attention already has been called to the fact that atresia of the external auditory canal may follow trauma. That fractures of the base of the skull may affect the ear also is well recognized. In the latter the fracture line often cannot be demonstrated roentgenographically. Clouding of the mastoids, with or without fluid in the tympanic cavity, is a secondary manifestation of the injury which often is the only roentgen abnormality in spite of classical clinical complaints indicating severe ear damage. Fractures and dislocations of the ossicles may complicate these injuries;[1] in rare instances mere cleaning of the external auditory canal of wax has been enough to cause this damage.

Aero-otitis media (barotrauma), another form of trauma, has been recognized as a complication of flying since 1783, when a balloonist experienced severe pain in an ear at an altitude of 10,500 feet.[7,17] Found most commonly in aviators the condition may affect also caisson workers and divers; indeed, any occupation which can initiate a difference in pressure between the tympanic cavity and the surrounding atmosphere may cause aero-otitis media.[22,27] The only prerequisites are (1) that the eustachian canal be blocked and (2) that the ear drum be intact.

Clinically barotrauma is ushered in by a sensation of fullness and then pain in the ear. This happens when the flight level changes, particularly during descent when atmospheric pressure is greater than the

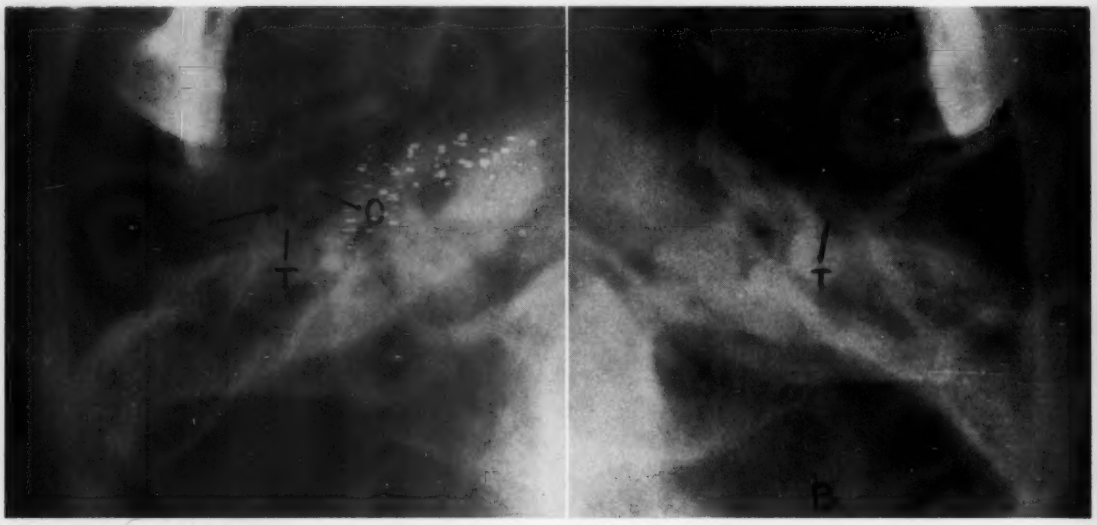

Fig. 18. Chronic otitis media. Submento-vertical projection. A male, thirty-six years of age, was admitted complaining of intermittent discharge from both ears of thirty-six years' duration. For six years no drainage was noted from the right ear. For the past seven years the left ear drained constantly. Physical examination revealed unusual thickening of the tympanic membrane of the right ear. A polyp protruded through a perforation in the left tympanic membrane. The general appearance of the right ear (*A*) is more normal than the left (*B*). On the right side (*A*) the general outline of the tympanic cavity (*T*) seems normal. The arrow points to a density considered to be the unusually thick tympanic membrane. The ossicles (*O*) are clearly defined and seem normal. On the left side (*B*) the walls of the tympanic cavity (*T*) are indistinct. There is no semblance of a normal ossicular shadow within this tympanic cavity.

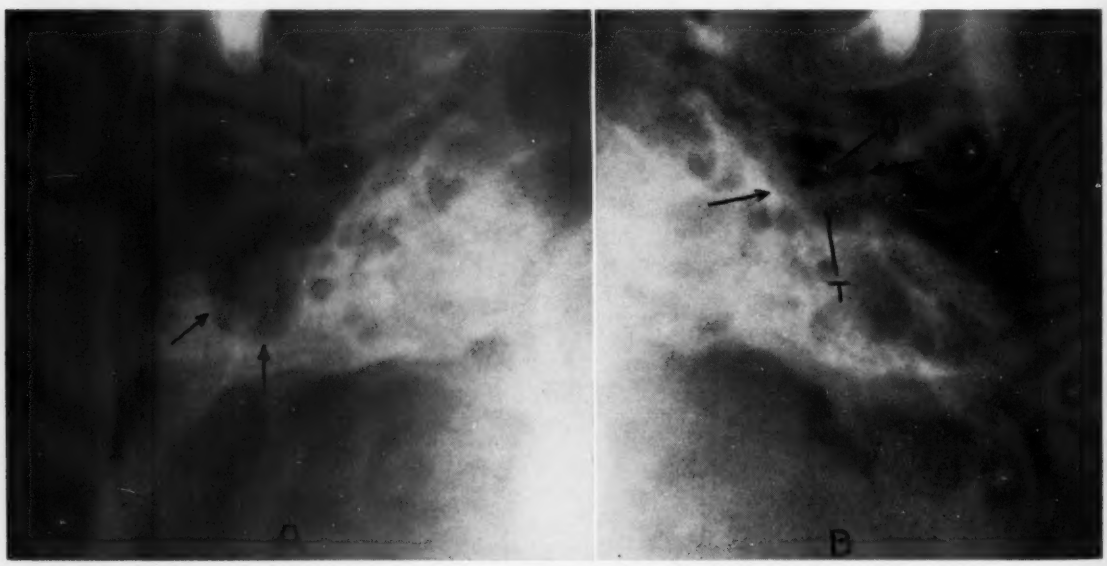

Fig. 19. Cholesteatoma. Submento-vertical projection. A forty-six year old female complained of intermittent discharge from both ears of over forty years' duration. Thick, creamy pus could be seen in both external auditory canals. The right ear (*A*) reveals a large radiolucent defect outlined by the arrows. It encompasses the region of the tympanic cavity and its immediate environs. The ossicles of the right ear cannot be identified. In the left ear (*B*) the tympanic cavity (*T*) is seen more clearly. A fluid level is seen with difficulty at the arrows. The ossicles (*O*) seem smaller than normal and somewhat deossified. At operation a huge cholesteatoma was removed from the right ear; no ossicles could be found. The left ear was not operated upon.

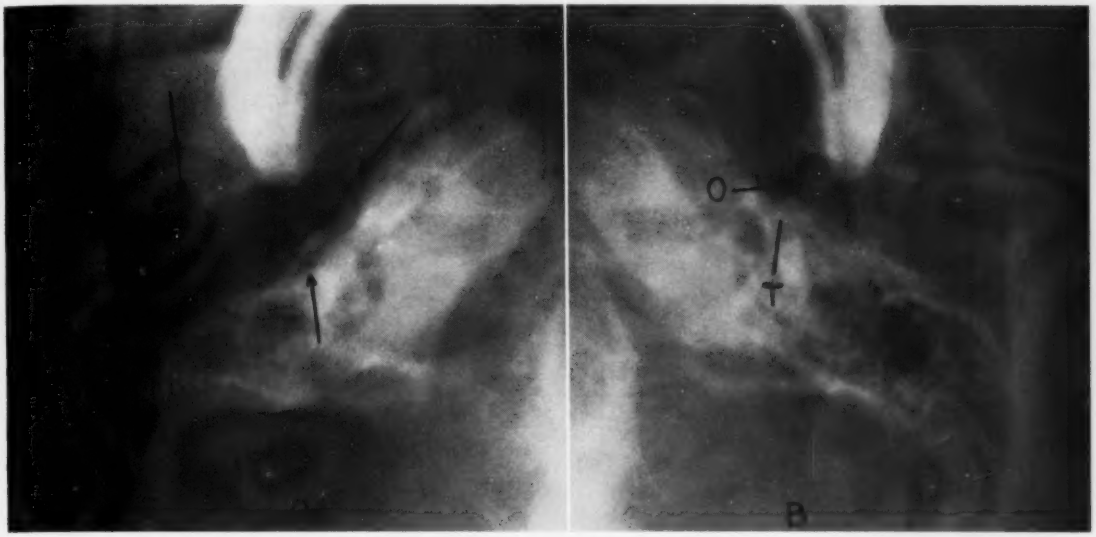

Fig. 20. Cholesteatoma. Submento-vertical projection. The patient, forty years of age, complained of discharge from the right ear since the age of two. Fifteen years prior to this examination a radical mastoidectomy was performed on the right side. The left ear was normal. A large radiolucent defect may be seen in the right ear (*A*). The ossicles apparently were removed at the time of the radical surgical procedure. The healthy left ear reveals no abnormalities. The tympanic cavity (*T*) and the ossicles (*O*) are clearly defined. At operation following the present examination a large cholesteatoma was removed from the middle ear on the right side.

air pressure within the occluded tympanic cavity. At pressure gradients of more than one-half atmosphere, the tympanic membrane often ruptures. Severe earache, vertigo, tinnitus and deafness may follow.

Roentgenographically aero-otitis media is characterized by retraction of the ear drum plus a shift in the axis of the ossicular chain. Larkin[19] demonstrated this in aviators; using opaque media he was able to follow the configuration of the ear drum as it relaxed or retracted. By plotting carefully the outline of the ossicles, Larkin showed that they changed in alignment as the ear drum changed. With the presence of vascular engorgement, exudation, hemorrhage, and inflammation, Larkin revealed alterations in radiolucency in the temporal bone. As these soft tissue responses to barotrauma progressed there followed a progressive decrease in the amount of air contained within this region. Roentgenographically the latter is reflected by loss of detail in the eustachian canal, diffuse increased density of the mastoid, opacification of the tympanic cavity, and, in rare instances, fluid levels within the tympanic cavity.

SUMMARY

1. The tympanic cavity and its contents may be demonstrated roentgenographically in routine roentgen examinations of the temporal bone made in the submento-vertical (Hirtz) and axial projections.

2. In congenital atresia of the ear important detail may be gleaned from roentgen examinations of the temporal bone.

3. The absorption of air from the eustachian canal and tympanic cavity occurs commonly with infection, inflammation, or trauma. Manifest roentgenographically as a decrease in the radiolucency of these structures the changes are seen best in the submento-vertical projection.

4. The ossicles participate in many abnormalities of the hearing apparatus; these changes may be also demonstrated by roentgen methods.

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RHINOLITH*

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A RHINOLITH may be defined as a nasal calculus or concretion, which forms as a result of complete, or partial incrustation of an intranasal foreign body, usually exogenous, but occasionally of endogenous origin.

CLASSIFICATION

Rhinoliths can be divided into the true or endogenous type and the false or exogenous type.

True rhinoliths are those formed around a nucleus of inspissated mucus, blood or nasal crusts. False rhinoliths are those formed around a foreign body nucleus such as a nut shell, bead, seashell, coal dust, fruit stone, vegetable matter, cement, hair, screw, button or splinter.

In either type, there is a deposit about the nucleus of inorganic salts of calcium, phosphates, magnesium, and sodium chloride derived from the nasal and lacrimal secretions.

ETIOLOGY

Rhinoliths may occur from a stagnating nasal discharge due to nasal obstruction, tuberculosis, fungus infection, cholesteatoma or chronic rhinitis. In the case of an exogenous foreign body, secondary nasal infection with subsequent incrustation with calcium salts occurs.

SYMPTOMS

Rhinoliths may occur at any age. Females usually outnumber males in most series. There is unilateral nasal discharge, recurrent epistaxis, foul breath, anosmia, and headache. Complications may be those of rhinitis, sinus tract formations, nasal obstruction, or secondary obstructive sinusitis.

DIAGNOSIS

One should suspect clinically the possibility of a rhinolith if given the above mentioned symptoms. Nasal examination with careful probing may result in the discovery of a calcified mass incrusted in the nasal passage usually accompanied by a purulent rhinitis.

Roentgenograms can contribute real help in the diagnosis of rhinoliths, providing that the concretion contains sufficient calcium salts to be radiopaque. Some rhinoliths unfortunately are radiolucent. Posteroanterior and lateral roentgenograms of the nasal area will show the calcified rhinolith in constant relation to the nasal passage. They may vary in size from small granules to gigantic masses completely obstructing the nasal chamber. Local bone absorption about the nasal passageway may occur due to pressure by the rhinolith and secondary osteomyelitis. The nasal septum may be deviated if the mass is large.

Differential diagnosis includes granuloma, neoplasm, syphilitic sequestration, calcified polyps, osteoma, necrotic bone from osteomyelitis and chronic sinusitis.

REPORT OF CASE

In August, 1949, a thirty-two year old white male gave a six year history of intermittent nasal discharge and obstruction, and occasional bloody streaks in the nasal secretions. Upper respiratory infections accentuated the symptoms. No allergic or other respiratory symptoms could be elicited. He had always been in good general health.

The patient was told by a rhinologist one year previously that he had "purulent sinusitis," especially on the right side. Radiation therapy to the maxillary sinuses gave relief of

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Fig. 1. Posteroanterior roentgenogram of nasal area showing calcified rhinolith in the right inferior meatus.

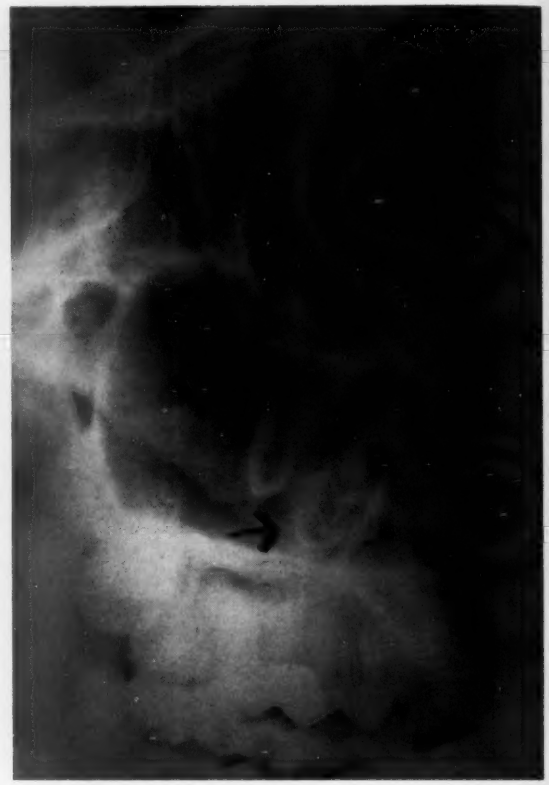

Fig. 2. Lateral view of nasal area showing calcified rhinolith in anterior third of inferior meatus.

symptoms for approximately four months. Recurrence followed the next upper respiratory infection.

Examination in August, 1949, by another rhinologist revealed an incrusted calcific foreign body in the inferior meatus of the right nares, which was then removed. All nasal symptoms quickly disappeared, and for the past five and one half years, there has been no recurrence.

Preoperative roentgenograms of the paranasal sinuses revealed a 14×17×11 mm. stippled irregularly shaped calcific mass located on the right in the inferior meatus in the anterior third of the nasal fossa quite consistent with a rhinolith (Fig. 1 and 2). A roentgenogram taken of the removed rhinolith (Fig. 3) shows the dense calcium content.

COMMENT

A rhinolith may simulate sinusitis and may be so diagnosed by a competent rhinologist. By considering the possibility of a

Fig. 3. Roentgenogram of surgically removed rhinolith.

rhinolith and making proper nasal and roentgenographic examinations, the diagnosis may be established. Removal of the stone usually affords the patient quick and permanent relief.

CONCLUSIONS

1. Rhinolith has been discussed.
2. A case report and the roentgen findings are presented.
3. The fact that rhinolith may simulate sinusitis clinically is emphasized.

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ROENTGENOGRAPHIC FINDINGS IN TRIGEMINAL NEURALGIA*

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TAARNHØJ in 1952 advanced the theory that trigeminal neuralgia is due to pressure on the sensory root of the fifth nerve where it crosses the apex of the petrous bone. He relieved ten consecutive cases by incising the dural sheath which overlay this part of the nerve. Abundant evidence has since accumulated to show that this operation does indeed relieve trigeminal neuralgia.[2,3,4,7,11] Gardner and Pinto[4] in 1953 expressed the opinion that pressure on the sensory root induces tic douloureux by causing atrophy of the insulating myelin sheath which in turn permits the development of a short-circuiting of the action current accompanying the passage of the nerve impulse. They suggested that compression of the nerve root may occur in some cases as the result of a relative upward displacement of the petrous apex due to basilar impression, and that the reason that trigeminal neuralgia is more common in elderly women may be because they are subject to postmenopausal osteoporosis which, according to their view, should favor the development of basilar impression.

Since the development of this theory we have compiled a study of 130 consecutive patients with unilateral or bilateral trigeminal neuralgia who have had special roentgen studies of the skull. In this technique, a posteroanterior exposure is made so as to project the petrous bones through the orbits. A line is drawn through the roofs of the orbits, and the height of each petrous bone at the point where the sensory root crosses it is measured from this line. The point of crossing of the sensory root is usually indicated by a slight depression at the apex of the petrous bone (Fig. 1). In this series the posteroanterior films of 115 unilateral cases were satisfactory for accurate measurement. On the lateral view in each of the 130 cases, the relationship of the tip of the dens to McGregor's line was measured. This is a line drawn between the posterior end of the hard palate and the lowest portion of the occipital bone (Fig. 2).*

In addition, similar roentgen studies were made in the cases of 200 adults in whom an intracranial lesion was suspected, but who did not have trigeminal neuralgia. As shown in the accompanying chart (Table I), in the 200 controls the apex of the right petrous bone was higher than the left in 47.5 per cent. The left was higher than the right in 29 per cent, and in 23.5 per cent the apices of the petrous bones were of equal height. The tip of the dens was 5 or more mm. above McGregor's line in 23 per cent of the cases (Table II). The average level of the dens for women was 2.4 above and for the men 2.2 mm. above. There were 104 women and 96 men. The average age was 45.7 years. From McGregor's study of 204 skulls, the majority of which were young adult males under investigation for suspected fractures, he considered a level of 4.5 mm. above the line the extreme upper edge of normality and to be encountered in approximately 1 case in 75. In his series he found the mean level of the dens to be 1.32 mm. below the line with a standard deviation of ± 2.62 mm. This high incidence of

* Chamberlain's line[1] is a line drawn between the posterior end of the hard palate and the posterior rim of the foramen magnum. Since the foramen magnum participates in the indentation which represents basilar impression, McGregor's line was considered more satisfactory than Chamberlain's line for measuring the relative upward migration of the dens and the base of the skull.

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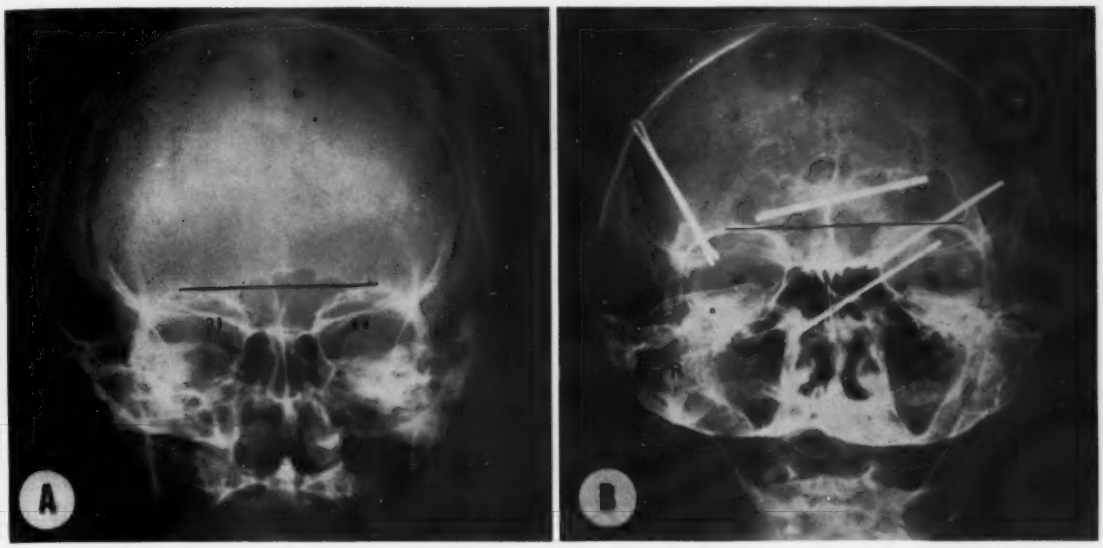

Fig. 1. (*A*) Case of right trigeminal neuralgia. The apex of the right petrous bone is 3 mm. higher than the left. (*B*) Case of bilateral trigeminal neuralgia in a patient with congenital basilar impression. Note the upward slanting of the petrous ridges. The neuralgia developed first on the right side in this case.

pathologic levels (by his standards) in our controls was unexpected and requires further scrutiny.

The figures in our controls show that the apex of the right petrous bone is apt to project farther into the cranial cavity than the apex of the left. We believe that this is a reflection of the fact that more people are right-handed and therefore are more inclined to use the right hand for heavy lifting. In carrying a suitcase, for instance, the neck and shoulder muscles contribute their share of the muscular contraction and this contraction tends to shorten the neck by exerting a downward pull on the base of the skull. In effect, because of the attachment of the cervical muscles, the suitcase is partially suspended from the base of the skull. This downward pull, of course, is countered by an upward thrust of the cervical spine

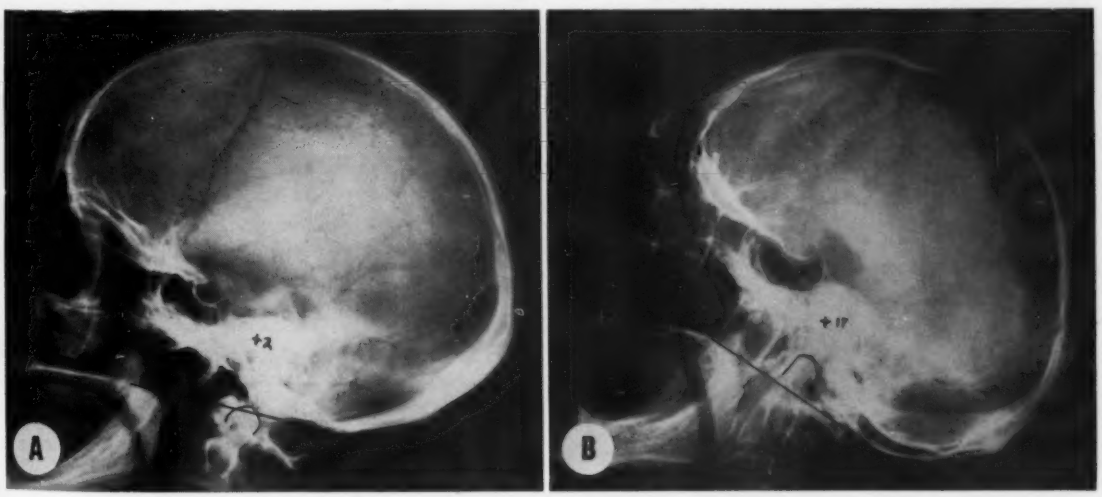

Fig. 2 (*A*) Same case as Figure 1*A*, illustrating a normal relationship of dens to McGregor's line. (*B*) Same case as Figure 1*B*. The top of the dens is 17 mm. above McGregor's line.

TABLE I

Controls	Right Petrous Higher	Left Petrous Higher	Petrous Equal Height
	%	%	%
200 cases	47.5	29	23.5
104 women	46.2	29.8	24
96 men	49	28.1	22.9
Trigeminal Neuralgia			
	%	%	%
115 cases	46	34	20
69 women	48	32	20
46 men	43	36	21

The right petrous apex is apt to be higher than the left in patients with or without trigeminal neuralgia. In patients with trigeminal neuralgia the disparity is more striking in women than in men.

TABLE II

Controls	Average Age	Dens Mean Relationship to McGregor's Line	Dens 5 mm. or More above McGregor's Line
	years	mm.	%
200 cases	45.7	+2.3	23
104 women	43.1	+2.4	26
96 men	47.7	+2.2	20
Trigeminal Neuralgia			
	years	mm.	%
130 cases	60.5	+3.99	43.1
84 women	61.5	+4.8	47.6
46 men	58.8	+2.5	34.8

Relationship of the dens to McGregor's line in a series of controls as compared to patients with trigeminal neuralgia. In McGregor's series, the majority of which were young adult males, he found +4.5 mm. to represent "the extreme edge of normality." According to his experience, therefore, the last column above represents cases of basilar impression.

which tends to displace the center of the base of the skull upward. The portion of the skull which is pushed upward (*i.e.*, impressed) in basilar impression is the portion surrounding the articulation with the cervical spine and this includes the apex of the petrous bone.

In the 115 patients with unilateral trigeminal neuralgia, 62 per cent were women and 38 per cent were men. In 60 per cent the trigeminal neuralgia was on the right side and in 40 per cent it was on the left (Table III).† In this series, study of the films disclosed the following: The apex of the right petrous bone was higher than the left in 46 per cent (Table I). The left was higher than the right in 34 per cent, and they were of equal height in 20 per cent. These figures are not much different from those for the controls. However, the neuralgia was on the side of the higher petrous apex in 60 per cent (Table IV), and on the side of the lower in only 20 per cent. The tip of the dens was 5 mm. or more above McGregor's line in 43 per cent (Table II). The average level in women was 4.8 mm. above and in men 2.5 mm. above. The above figures, therefore, indicate that basilar impression is more common in patients with trigeminal neuralgia than in the control series. They show that trigeminal neuralgia occurs three times as often on the side of the higher petrous ridge as it does on the side of the lower.

Two patients of this series of 130 cases of trigeminal neuralgia had Paget's disease of the skull, whereas this condition was found only once in a survey of 700 roentgenograms of the skull in patients with lesions

† Harris[5] reported his experience with over 1,100 cases of trigeminal neuralgia in 1930. He found that 66 per cent were women and 34 per cent were men, that 61 per cent had neuralgia on the right side and 39 per cent on the left. Of 60 bilateral cases 80 per cent were in women. The figures in our small series, therefore, correspond very closely with his.

TABLE III

115 Cases of Unilateral Trigeminal Neuralgia 60% right—40% left			
62% women		38% men	
63% rt.	37% lt.	55% rt.	45% lt.
13 Cases of Bilateral Trigeminal Neuralgia			
10 women		3 men	

Trigeminal neuralgia is more common in women and more common on the right side.

TABLE IV

HEIGHT OF APEX OF PETROUS BONE COMPARED TO THE SIDE OF THE TRIGEMINAL NEURALGIA

(115 unilateral cases)

Homolateral apex higher	60% (1–7 mm.)
Contralateral apex higher	20% (1–5 mm.)
Apices at same level	20% (less than 1 mm.)

Trigeminal neuralgia is three times as common on the side of the higher petrous bone than it is on the side of the lower.

TABLE V

AVERAGE HEIGHT OF DENS IN WOMEN WITH TRIGEMINAL NEURALGIA BETWEEN AGES 20 AND 90

	mm.
1 case in 3rd decade	+5
4 cases in 4th decade	+1.5
7 cases in 5th decade	+3.4
19 cases in 6th decade	+4.2
33 cases in 7th decade	+4.8
15 cases in 8th decade	+6.7
5 cases in 9th decade	+3.2

These figures indicate a definite upward migration of the dens in women with trigeminal neuralgia from the 4th to the 8th decade.

other than trigeminal neuralgia. In each of these 2 cases, the tip of the dens was 8 mm. above McGregor's line. In 1953 Poppel, Jacobson, Duff and Gottlieb[10] found basilar impression in 36 per cent of a series of 75 cases of Paget's disease.

Seven of our series of 130 cases of trigeminal neuralgia had multiple sclerosis and 1 of the patients with multiple sclerosis also had acromegaly. In only 1 of these 130 cases was the trigeminal neuralgia proved to be due to a tumor compressing the sensory root of the nerve. In another case it was probably due to compression of the root by an anomalous trigeminal artery.

The apex of the petrous bone constitutes a portion of the base of the skull which is pushed upward in the patient with basilar impression. In this condition the volume of the skull cavity is reduced by the process, and there results a relative migration of the intracranial structures in a caudad direction. This caudad displacement is particularly marked in the brain stem from which structure the sensory root of the trigeminal nerve arises. Because of this relative caudad migration of the brain stem, the sensory root of the trigeminal nerve becomes flattened and angulated where it crosses the apex of the petrous bone. Olivecrona[9] in 1947 called attention to the fact that the fifth and ninth nerves run upward from the brain stem toward the skull and he postulated that the action of gravity increases with age and causes traction on these nerves. He thought that this may be responsible in some way for tic douloureux. Lee[6] in 1937 called attention to the sharp angle which the sensory root of the fifth nerve makes where it crosses the apex of the petrous bone. He advanced the theory that tension from the bone beneath, together with compression by the superior petrosal sinus from above, could be the cause of trigeminal neuralgia. He states, "This idea can be put to the test by anyone who can elevate the superior petrosal sinus and remove some of the bone underneath the sensory root."

Table v shows the average height of the dens in women with trigeminal neuralgia in each decade between the ages of twenty and ninety. These figures show a progressive upward displacement of the dens between the fourth and the ninth decades. This progression was not obvious in the smaller series of men who were similarly analyzed. It could not be demonstrated in the control series in which, however, there were relatively few subjects in the older decades. We believe, therefore, that upward progression of the dens does occur in some aging women as the result of postmenopausal osteoporosis. It should be possible to demonstrate this in a properly selected control series.

SUMMARY

These studies show that there is a correlation between basilar impression, age, sex and trigeminal neuralgia, and that postmenopausal osteoporosis with resulting basilar impression probably explains why

trigeminal neuralgia is more common on the right side and in elderly women.

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THE EFFECT OF SINGLE DOSES OF ROENTGEN RADIATION ON EXPERIMENTALLY INDUCED GLIOMAS:

WITH A CRITICAL REVIEW OF THE EFFECTS OF ROENTGEN RADIATION ON GLIOMAS IN MAN*

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AT THE present time roentgen therapy of human gliomas is generally used as an adjunct to operative treatment. A few neurosurgeons sometimes are content with simple biopsy of the glioma and the use of irradiation as the principal therapy. Most would attempt to remove the neoplasm as completely as possible and then use radiation therapy for further control. Although irradiation without histologic proof of the lesion has been suggested, under most circumstances neurosurgeons and radiologists prefer confirmation of the neoplasm. Patients with inaccessible tumors in deep structures such as the midbrain may be given radiation without verification of the lesion. Radiation therapy has been used for all the known types of primary brain tumors.

Agreement is general that of the gliogenous neoplasms, medulloblastoma is the most readily affected by roentgen rays. Despite this, it is well recognized[3,7] that medulloblastomas, which are histologically and clinically similar, may differ widely in response. The sensitivity of other types of gliomas is less well documented.[7] Most workers have found that the oligodendroglioma is not radiosensitive. Ependymoma and astrocytoma may or may not respond, and the degree of declared success varies with different workers. There is little evidence that the course of a patient with glioblastoma multiforme is altered,[18] and yet there are scattered reports of "good," but transient responses.[21] There are no reliably reported cures of a human glioma of any type as the result of radiation therapy. Increased dosages, more feasible with the development of better machines, have not yet resulted in benefits,[10] but it is still too early to evaluate this work. Increasing numbers of reports of radiation damage to the nervous system suggest that these technical advances are a mixed blessing.

Benefit to the patient with an intracranial or intraspinal neoplasm as a result of radiation therapy is based principally on two critera: (1) the response of the patient in terms of neurologic signs and symptoms and (2) the duration of life after therapy. These indirect methods must be used because direct observation of the size of the tumor is not usually feasible. In addition, there have been a few reports[1,6,22] of histologic changes in tumors studied before and after the delivery of ionizing radiation. These anatomic changes have not been well correlated with the intensity of radiation, nor the observed clinical effect, nor the survival period.

Because opinions as to the merit of radiation therapy vary widely, it was thought that a critical inquiry into the problem might be of value. Such a review may lead to an understanding of the different findings obtained by individual workers, and the variations in results from different clinics.

Improvement after irradiation of patients in whom histologic verification of neoplasm has not been made should be dis-

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carded from consideration. "Therapeutic trials" made so blindly have no scientific validity.

If the existence of neoplasm is confirmed by biopsy, interpretation of the value of later therapy is immediately complicated, because patients may be benefited symptomatically by the decompressive procedure (internal and/or external). Some or all of the value attributed to radiation therapy administered after craniotomy may be due to the effects of decompression. This is especially true of short-term results, occurring within a few days or weeks after the operative procedure.

Clinically, the course of a patient with an intracerebral glioma may alter spontaneously for better or worse. This is discussed in greater detail in a separate publication.[19] The progressively deteriorating course of these patients has been overemphasized in the past. This misconception has resulted in the attribution of symptomatic improvement to radiation therapy but deterioration is blamed on the disease. Spontaneous improvement may occur and is temporary, but on occasion may last for many months. Transient edema of the tumor or of the surrounding tissue, intermittent blocking of blood vessels or dural sinuses, variations in the state of hydration and electrolyte balance, and other factors may combine to produce variations in the clinical picture. Even the most highly malignant gliomas, such as glioblastoma, may be compatible with many years of life.[18] The location of the tumor may be an important factor in this—large areas of the brain are "silent"; infiltration of tumor may occur without blockage of the ventricular system. The natural history of gliomas is sufficiently variable to make the efficacy of radiation therapy in an individual case a difficult evaluation. It is therefore necessary to use comparative or statistical methods.

The relative rarity of gliomas makes statistical evaluation hazardous. It is unusual for a single individual or institution to obtain groups of patients large enough for adequate statistical analysis. This is true for gliomas as a whole, but even more so for individual types. Glioblastoma, medulloblastoma and astrocytoma usually are the overwhelming majority of cases. The remainder (ependymoma, etc.) represent only about 20 per cent of the gliomas. A series of adequate size, both treated and untreated, is difficult to obtain. Survival times must be compared, therefore, with averages obtained by other workers. This is always unsatisfactory because of large individual variations in the natural history of patients with gliomas, because of lack of uniformity of pathologic controls, and because different techniques of irradiation are used. The association of greater average survival time with larger doses of roentgen rays is not necessarily a cause and effect relationship. In the first place, too many exceptions are encountered in which low, presumably inadequate dosages and long survivals are associated, or in which extremely high doses and brief survival are correlated. Furthermore, larger total doses may be given because the patient lives longer rather than the reverse. Some patients may survive a longer time because of roentgen radiation, but although it is easy to accept this idea, proof is difficult.

A properly controlled statistically significant series is almost impossible to obtain in human beings. This implies that one series of clinically and histologically similar cases would not receive irradiation, and another series would receive irradiation in a standardized fashion. Lacking such a series, methods of analysis must be indirect, and comparisons made of groups which may not be comparable.

Since the full extent of a gliogenous tumor cannot be known without *complete* postmortem study, radiation is given widely over the biopsied site, but without assurance that the entire tumor is treated. This introduces still another variable factor, because it is not known what proportion of the neoplasm actually received the calculated depth dose. Experimental evidence is presented in this paper that failure to treat the entire tumor may be more dan-

gerous than failure to treat at all. In any event, this becomes another uncontrolled and unknown factor.

Finally, still another problem of interpretation is brought forward by the experimental data to be discussed. Growth curves of the transplants of similar unirradiated tumors vary significantly from one animal to another, although the conditions of transplantation are highly standardized. The histologic appearances offer no hint of this biologic variability. It is suggested that the rates of growth of human gliomas may vary similarly within a given histologic subgroup.

Pathologically, the problem is no less difficult. A biopsy taken during a craniotomy may not be representative, *e.g.*, biopsy of the astrocytic edge of glioblastoma multiforme is a not infrequent occurrence. Even with the entire tumor available at necropsy, a single paraffin section may be misleading, because most gliomas are pleomorphic and differ in appearance in various parts even within the limits of a single paraffin block. Serial biopsies at different times in the course of growth of the tumor are usually difficult to obtain in man. It is indeed good fortune to be able to study two specimens—one at the time of craniotomy, and one at necropsy. Even if repeated biopsies could be obtained, the limited specimens might be misleading, rather than representative. Nearly all changes attributed to radiation may occur spontaneously in gliomas. These changes include the presence of multinucleated giant cells, foci of necrosis, calcification, fibrosis, and hyalinization and proliferation of blood vessels. The diagnosis itself is difficult to achieve in some instances, and hence the comparability of particular categories of gliomas is questionable when the diagnoses are furnished by different pathologists. This is illustrated by the Cushing series where glioblastoma multiforme represented only 25 per cent of gliomas in contrast to most modern series such as that of Montefiore Hospital[18] in which the incidence is about 50 per cent. Recent new classifications only add to this problem.

Some clinicians and roentgenologists have contended that even if there is an uncertainty about the results of roentgen therapy in the treatment of gliomas, treatment is advisable on the grounds that it might help the patient, and can do little harm. The possibility of benefit has had support especially in the medulloblastomas, but the evidence that other types of gliomas are benefited is at least open to question. There is, however, an increasing mass of data to indicate that harm, sometimes great, may result from radiation therapy. Early reports dealt with acute reactions to radiation therapy such as nausea, vomiting, and greater increase in intracranial pressure. These are still encountered, and should enter into consideration. In children, there may be effects on the growth of bone;[20] other potential hazards have been discussed by Miller.[16] In the adult, radiation myelitis and necrosis of brain have been described many times,[15] and recently additional evidence has been presented of harmful effects on white matter, hypothalamus and brain stem.[2,4]

For these many reasons, judgment of the value of radiation therapy of human gliomas is dependent on clinical impressions rather than on verifiable facts. It was thought that some of these difficulties might be resolved by studying the effects of roentgen rays on gliomas in experimental animals. Measurement is relatively easy, because the tumors are maintained subcutaneously. The histologic and biologic behavior of these tumors has been studied through many successive generations. Large numbers of animals can be used, and each can receive similar tumor implants. Serial studies are easy to perform. Many control animals can be used. The questions of location in brain and relation to ventricular system are not complicating problems. Insofar as the tumors are histologically indistinguishable from human gliomas, they are at least morphologically comparable. The problem of the applicability of these data obtained in mice to man is an impor-

tant one, and cannot be settled here, but an approach may be made in this direction by comparing these findings with adequately controlled data in man. It is hoped that these experiments will stimulate further studies.

METHODS AND MATERIALS

The mice used were of three different strains—C57 BL, C3H, and A albino. In each of these strains, brain tumors can be induced by prolonged application of a suitable carcinogen.[24] The tumors studied were induced in the brain of a mouse and further passage was always carried out in mice of the same strain. The neoplasms were then carried through successive generations as subcutaneous transplants. The techniques of transplantation are simple and have been described.[24] Histologically, each of the tumors was a malignant glioma designated as ependymoblastoma.

The subcutaneously situated tumor was irradiated tangentially while exposed through a slit in a lead chamber, to avoid damage to internal organs. The controls were mice with tumors which were similarly handled in lead tubes, but were not irradiated.

The lead chamber[9] is shown in Figure 1. The original experiments were done in chambers with lead walls of 2 mm. thickness, the later experiments with 3.7 mm. walls. With the latter, there was 0.6 per cent transmission. The lead binding strips used to immobilize the tumors were of the same thickness. At 3.7 mm., the combined binding strip and chamber overlap allowed only 0.2 per cent transmission.

The chamber had air holes at one end and was corked at the other. The opening through which the tumor was extruded was 3.0×1.5 cm. in area. The mouse was placed in the chamber, then the tumor was gently drawn out and immobilized with the binding strips. Placement of the strips was secured with scotch tape.

Three or 4 animals were irradiated at one time. Only the uniform portion of the field was used, forming a circle 10 cm. in diameter. The physical factors were: 200 kv., 25 ma.; the half-value layer was 0.9 mm. Cu. The machine delivered 178 r per minute in air.

The tumors were fixed promptly in 10 per cent formalin when the animals were killed. Selected portions were embedded in paraffin and studied routinely by the hematoxylin and eosin technique. The Mallory phosphotungstic acid, Wilder, Masson and periodic acid methods were also utilized in selected instances.

The first experiments were performed for purposes of orientation, and to determine the sequence of changes in the histologic appearance of the irradiated tumor. Roentgen unit doses of 400 r, 800 r, 1,200 r to each of 6 mice, and 3,000 r and 5,000 r to each of 10 mice were used. Similar numbers of unirradiated control mice were studied. The mice were sacrificed in pairs at intervals after irradiation. Measurement of the tumor was made at death, and the averages are shown in Figures 12 and 13. Having obtained a sequential study of the ap-

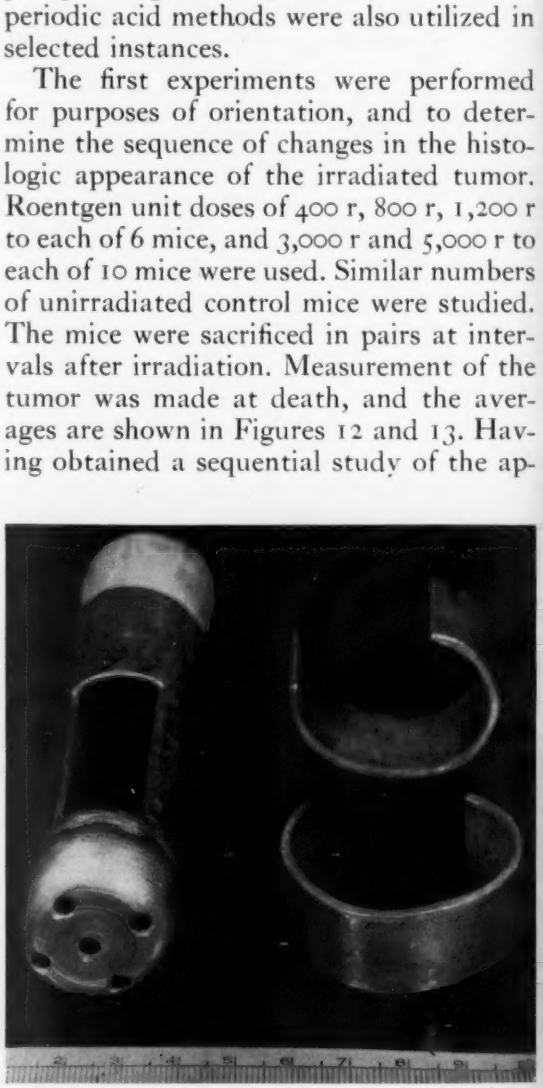

FIG. 1. Lead chamber with window for extrusion of tumor is shown on left. The chamber is corked above, and air holes are seen below. The protective binding strips are on the right.

pearance of the tumor, and some insight into the size of doses necessary to produce the desired effects, experiments were then designed so that each tumor was measured in the animal at intervals after irradiation rather than only at the time of sacrifice. This provided a better opportunity to study the effect of irradiation on the *rate* of growth.

In all subsequent experiments, therefore, the tumors were measured in 3 dimensions with calipers at 2 to 3 day intervals and the volume of the tumor was calculated. At the same time, the mice were weighed to within 0.5 gm. on a beam balance.

Volume measurements fall short of ideal as a means of determining the amount of viable tumor. Accumulation of fluid may alter the volume, and necrotic or nonviable tumor of unknown size may be present. The bizarre shapes assumed by the tumor frequently make it difficult to measure the volume accurately. The edge of the tumor is at times difficult to determine.

The weight measurements, in general, followed the same curve as the tumor size. But wasting of the body of the animal was sometimes present in instances where the tumor was increasing in size. Weight measurements suffer also from some of the above cited difficulties—failure to account for fluid or necrotic tumor. The weight of the animal was found to be a reasonably good indication of the general condition of the animal. When the animals became sick, they lost weight, whereas in health, they maintained or gained weight.

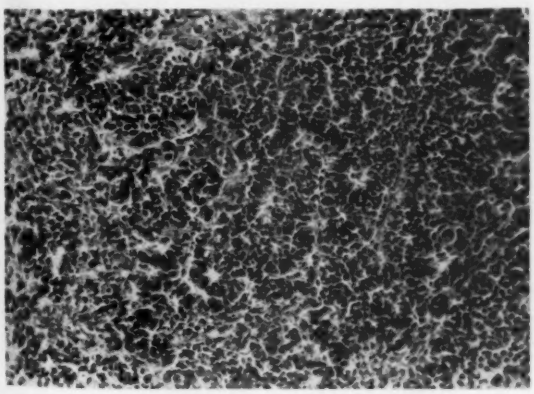

Fig. 2. Photomicrograph of unirradiated ependymoblastoma. Numerous rosettes are present. Hematoxylin and eosin stain ×150.

Most of the animals in these later experiments were not killed until they appeared so ill that death was imminent. In a few instances when death was not anticipated, the animal was found putrefied, but in all other cases, portions of the tumor were taken for microscopic study.

RESULTS

These will be considered separately as histologic and biologic effects.

A. *Histologic Effects.*

The tumor chosen for study, an ependymoblastoma, had been passed through more than 40 generations in successive subcutaneous transplants. Although originally a mixed glial neoplasm, histologic standardization was achieved in the early transplants, and all later generations were of a uniform pattern in microscopic preparations. The cells were arranged in sheets, but frequently formed rosettes or papillae around amorphous cores, or around the walls of blood vessels (Fig. 2 and 3). The individual cells were usually carrot-shaped with the nucleus at the broad end, and a small cytoplasmic tail at the narrow end (Fig. 4). The cytoplasm was agranular and much smaller in volume than the nucleus. The latter was oval to round, and contained many large and small chromatin clumps within a sharply defined nuclear membrane. Occasional bi- and tri-nucleated cells were scattered through the mass. Mitoses were small in number. Foci of necrosis occurred spontaneously in these unirradiated animals. The blood vessels in such foci were thin-walled and were never thrombosed. This was also true of the vessels in the remainder of the tumor. Vascular proliferation and endothelial proliferation did not occur in these control neoplasms.

The most striking histologic effects in these tumors were obtained with the larger doses of roentgen rays. Pairs of unirradi-

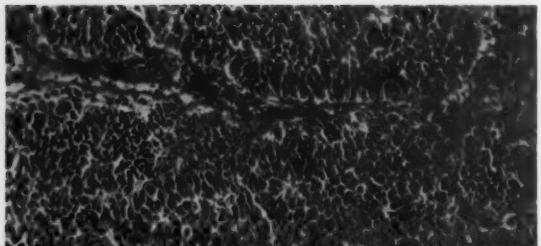

Fig. 3. Papillary formations and occasional giant cells are seen in this unirradiated neoplasm. Hematoxylin and eosin stain ×150.

ated controls were studied with each pair of irradiated mice. The successive controls served to determine the effect of increased size of the mass and of greater age on the appearance of the unirradiated tumor. These controls did not demonstrate a significant degree of variation related to size or age in the period studied. All the changes described below were confirmed by the less systematic material obtained in the subsequent larger studies of growth rates.

5,000 r. The neoplasm was studied four, nine, fourteen and twenty-five days after irradiation. In four days the characteristic rosette and papillary formations had almost completely disappeared (Fig. 5). The shape of the cells changed from the carrot shape of the ependymoblast into at least three different types (Fig. 6). The most frequent new form was a cell with swollen, voluminous cytoplasm of irregular shape, ameboid in appearance. Other cells became monstrously big and frequently were multinucleated. A few cells became tadpole-shaped, with one or two processes and thus resembled uni- or bi-polar spongioblasts. The nuclei underwent significant alterations, also of three general types. Some nuclei became swollen from one and a half to three times the size of the usual nucleus in the control material. These nuclei contained irregular clumps of chromatin. Other nuclei became dark and pyknotic, and details of chromatin arrangement could not be recognized. The third nuclear change was the formation of multinucleated giant cells, presumably by amitotic division. Giant cells contained in some places vesicular nuclei, and in other places pyknotic nuclei (Fig. 6). There was a tendency for the pyknotic cells to be clustered in small foci, either within the tumor or at the edge of a few small zones of necrosis. The endothelium of blood vessels was moderately swollen in some foci, but this was not striking, nor were occlusions noted.

When studied nine days after irradiation

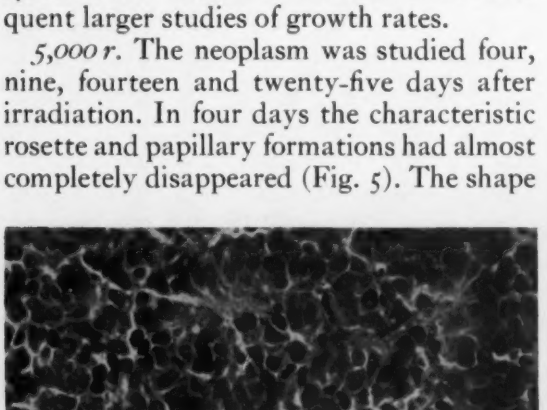

Fig. 4. Higher power view of control tumor showing form of cells and rosettes. Hematoxylin and eosin stain ×550

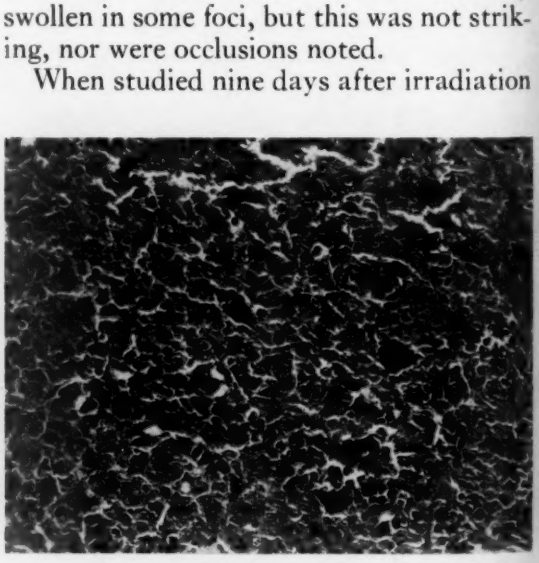

Fig. 5. Appearance of the neoplasm four days after a single dose of 5,000 r. The cells are swollen, and many new forms have appeared. Compare with Figures 2 and 3. Hematoxylin and eosin stain ×150.

the neoplasms still bore no resemblance to the original ependymoblastoma. The nuclei were still very much swollen or shrunken, or were multiple within a single cell body. Connective tissue ingrowth appeared from the surrounding tissues. Scattered macrophages and mononuclear cells also were seen at the periphery of the tumor. There was little alteration of blood vessels.

By fourteen days some tumors had completely disappeared, and only macrophages and mononuclear cells marked the site of the transplant (Fig. 7). When present, the tumor consisted mainly of large, bizarre multinucleated cells (Fig. 8). Most of the nuclei were pyknotic, but some were vesicular. Connective tissue had continued to proliferate, and bands of such tissue isolated islands of bizarre cells. Blood vessels were normal in appearance.

Study was made twenty-five days after irradiation in the instances where the tumor regrew after initial depression of growth. This revealed an appearance in which some of the original pattern had returned. Scattered rosettes were present, but in a background of small, round, dark cells without particular arrangement (Fig. 9). Some bizarre and multinucleated cells were still present, greater in number than in the control, but fewer than in specimens examined shortly after irradiation. Many of the cells had regained their former carrot shape.

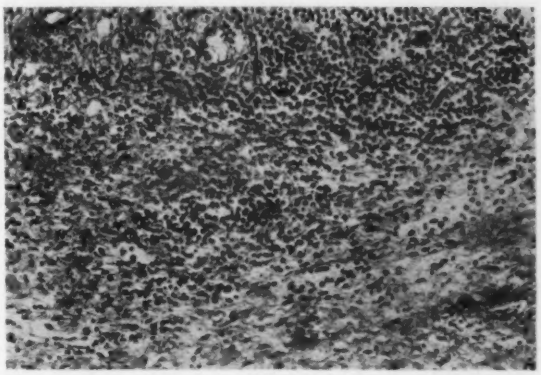

Fig. 7. Site of tumor transplant fourteen days after a dose of 5,000 r. Tumor cells are not present. Connective tissue, macrophages and lymphocytes are seen. Hematoxylin and eosin stain ×150.

As indicated in the discussion of biologic effects, when tumors which were regrowing after receiving large doses of irradiation were subsequently transplanted, their histologic appearance was similar to that of the controls. The effects of the roentgen rays are not carried over to the regrowing neoplasm.

3,000 r. The effect was in general similar to that described above. The differences were purely quantitative, being slightly less in degree. The tumor regrowing twenty-five days after irradiation, for instance, contained more ependymal ro-

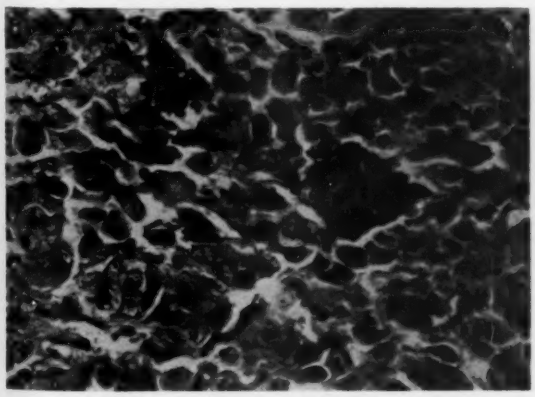

Fig. 6. Higher power view of tumor cells four days after receiving 5,000 r. Compare with Figure 4 at same magnification. Note swelling, multinucleation and bizarre forms of cells. Hematoxylin and eosin stain ×550.

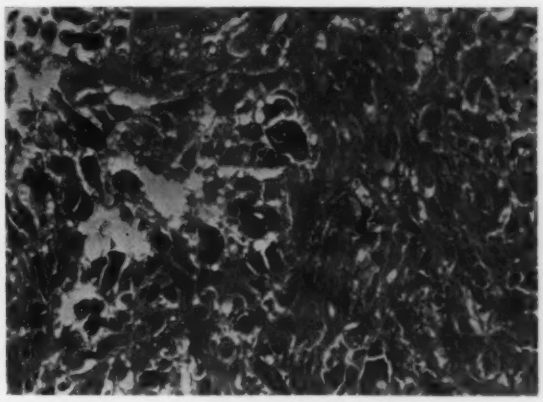

Fig. 8. Many multinucleated cells are noted in this section taken fourteen days after a 3,000 r dose. There is some proliferation of connective tissue. Hematoxylin and eosin stain ×550.

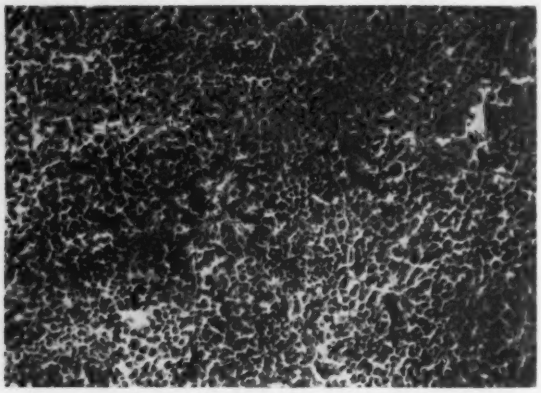

Fig. 9. Rapid regrowth of the tumor has occurred in this instance twenty-five days after administration of 5,000 r. Note the return of rosette formations and resemblance to original pattern. Hematoxylin and eosin stain ×150.

settes, but the general pattern was the same.

The effects of smaller single doses of roentgen rays were studied in a second series. As before, pairs of unirradiated mice were sacrificed together with pairs of irradiated animals at intervals of three, seven and thirteen days after therapy.

1,200 r. Three days after irradiation, portions of the tumor retained their rosette formation. Despite this, the cells forming the rosettes were altered in the fashion already described—with formation of large rounded cells, and a vesicular, or pyknotic appearance, or many nuclei in individual cells. Some of the elongated, "spongioblastic" cells were shown to be glial in origin with PTAH stains. In seven days, foci of necrosis appeared in the neoplasm. These were frequently bordered by characteristic large, multinucleated bizarre cells. Such foci were attributed to the effect of roentgen rays, because spontaneously occurring necrotic zones in the control specimens rarely had bizarre cells at the rim of necrosis. The ependymal character of the neoplasm was not recognizable at this time, an effect which occurred earlier in the more heavily irradiated tumors. Connective tissue ingrowth had now occurred. By the thirteenth day, many of the cells were less swollen, and portions of the tumor contained rosettes, which, though not as well defined as in control specimens, were nevertheless recognizable (Fig. 10). Foci of bizarre and altered cells persisted, and a few of these cells were scattered in parts of the tumor which appeared to be recovering.

800 r. The ependymal character of the tumor was still partially recognizable in three days. A moderate number of giant and bizarre cells was present. Swelling of the cytoplasm, and especially of the nuclei was prominent. In seven days, ependymal characteristics were lost. There were only a few foci of the dark, pyknotic cells, and the

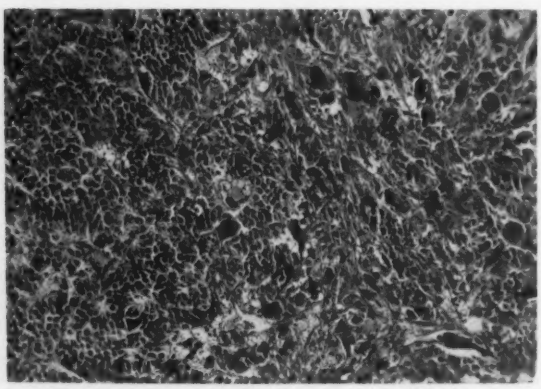

Fig. 10. Focal alterations thirteen days after delivery of 1,200 r. Multinucleated cells lie on the right; recovered, more normal ependymal cells are seen on the left. Hematoxylin and eosin stain ×150.

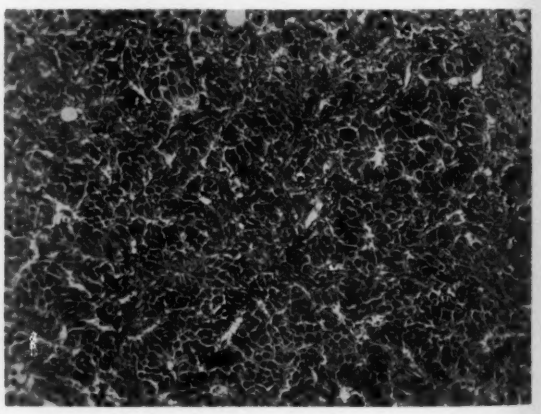

Fig. 11. Acute and transient swelling of cells three days after 400 r was given. Papillary and rosette formations can still be seen. Hematoxylin and eosin stain ×150.

majority of nuclei became enlarged and seemed to constitute most of the cell body. Giant cells surrounded the few foci of necrosis. By the thirteenth day, many rosettes were again recognized, but the presence of excessive numbers of bizarre and multinucleated cells made easy the recognition of the effect of irradiation.

400 r. This dose made only a mild alteration in the pattern of the tumor. Within three days the cells generally appeared swollen and were stained paler than in the controls (Fig. 11). A few multinucleated giant cells appeared, but foci of necrosis were not present in greater amount than in the unirradiated material. The tendency of some glial cells to become spindle-shaped (spongioblastic) was again noted. By seven days there was a combination of portions with rosette formation and portions with tumor cells forming parallel bands. Some foci of necrosis had now appeared with the usual associated giant cells. Recovery was almost complete by the thirteenth day, and only the presence of a few multinucleated cells gave evidence that the tumor had received radiation.

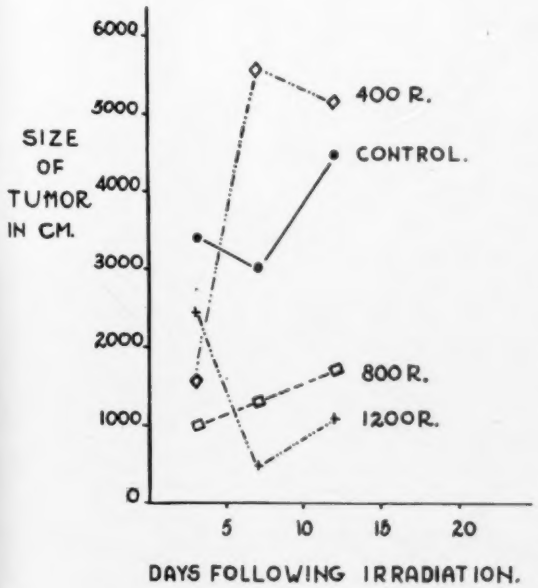

Fig. 12. Chart showing the effect of low doses of roentgen therapy on the size of the glial tumors. The apparent stimulation after 400 r was not confirmed in larger series. Each point represents the average of 2 tumors measured once in animals prior to sacrifice.

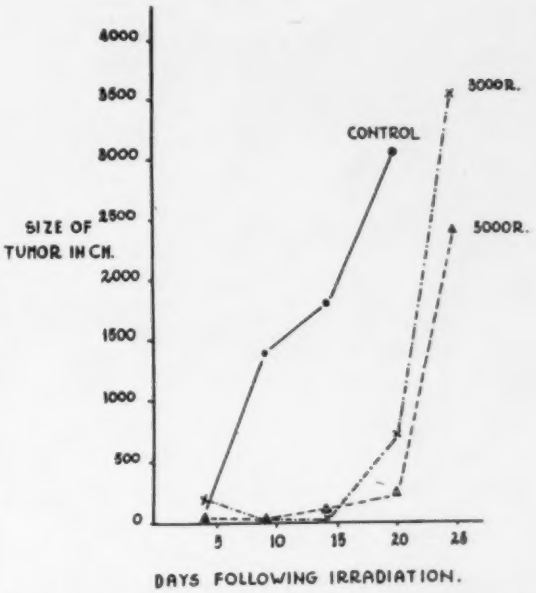

Fig. 13. Chart showing the effect of higher single doses of roentgen therapy. Each point has the same significance as in Figure 12. The material in these 2 charts was used principally for the histologic studies.

B. Biologic Effects.

1. The first experiment was designed to discover the effect of a wide range of single doses and to obtain material for the consecutive histologic study just cited. The C57 BL mouse was used, and an ependymoglastoma in the 43rd subcutaneous generation. The defects of single measurements of the tumor at death of the animal and of using only 2 animals have been discussed. Nevertheless, the results shown in Figures 12 and 13 suggested that 400 r might increase the growth of the tumor. This was not confirmed in the larger series studied later (see 2, 3 and 4 below). Doses of 800 to 1,200 r had a transient depressing action. A significant decrease in rate of growth was obtained with 3,000 and 5,000 r, but thereafter some tumors grew more rapidly after this initial decrease in size. All data were verified in subsequent studies, except for the presumed stimulating effect of 400 r.

2. Does 400 r have a growth stimulating effect? Using the same strain of mouse as in

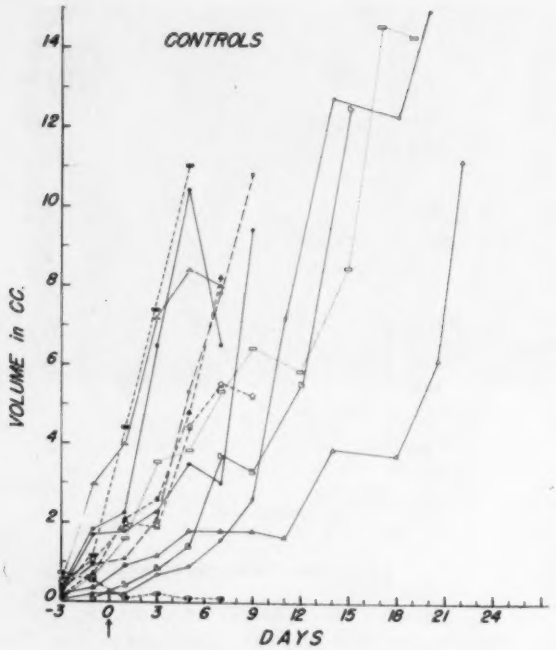

Fig. 14. Growth rate curves of individual unirradiated neoplasms are shown with days following irradiation on the abscissa and volume of tumor in cc. on ordinate. Each line represents the change in volume of an individual tumor measured at intervals shown by the points. Note the variability in growth rates from one animal to another. One transplant failed to grow.

the original experiment and the next generation of the same tumor, 8 mice received 400 r, with 6 animals serving as unirradiated controls. The rates of growths were similiar in the two groups. These rates were comparable to those described below, and therefore are not charted.

3. What is the effect of low and of high doses on rates of growth in a larger series? In this experiment mice of the C3H variety, and another but histologically similar ependymoblastoma were used. From 8 to 10 animals in a group received doses of 200, 400, 3,000 and 5,000 r, with one group similarly manipulated in tubes, but receiving no irradiation. The effect of these doses is shown in Figures 14–18. Some idea of the variability of tumor growth under these controlled conditions may be gained from Figure 14, which illustrates growth rates of tumors in unirradiated mice. In general, growth of the tumors is slow at first. The animal may die during the period of slow growth of the tumor, but in many instances, there is a final more rapid increase in size before death. In the control group shown in Figure 14, rapid late growth occurred in from ten to forty days after transplantation of similar material of similar volume from a single parent tumor.

The rates of growth of tumors receiving 200 and 400 r were comparable to those of the controls (Fig. 15 and 16). But at 3,000 r a different response was obtained (Fig. 17). After administration of this single dose of roentgen rays, the tumors either increased in size slightly for a few days and then became smaller, or, more commonly, diminished in size promptly after irradiation. Some tumors never recovered. A few others began to grow very rapidly from eight to fifteen days after irradiation, and after a period of depression of growth. This diphasic growth curve, in its second phase,

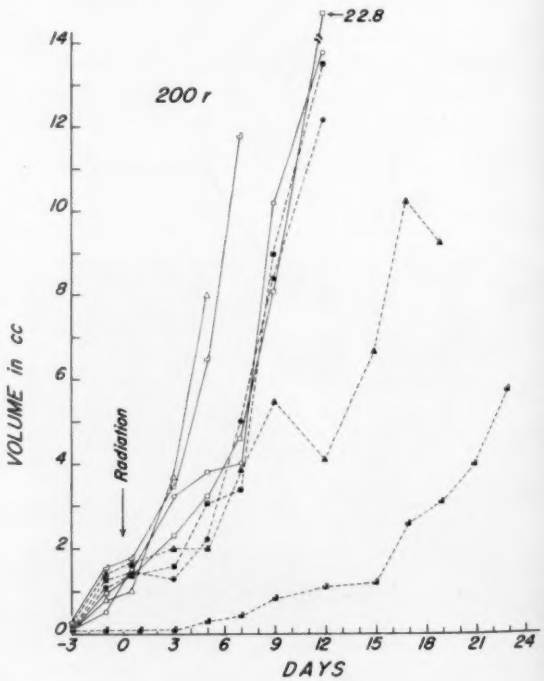

Fig. 15. Growth rate curves as in Figure 14. There is no significant effect of 200 r.

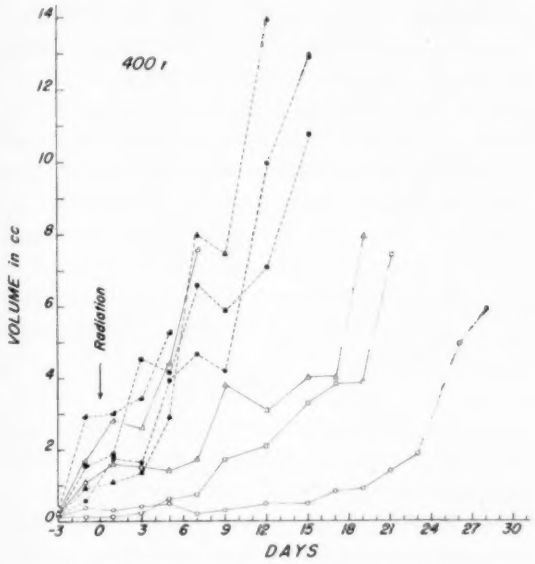

FIG. 16. Growth rate curves as in Figure 14. The administration of 400 r does not stimulate growth of the tumors.

was related to a mass which first became visible just outside the zone of epilation. A similar diphasic curve was obtained at 5,000 r in only 2 animals, and after a much longer interval of from twenty-three to thirty-five days after irradiation (Fig. 18).

Comment. There is great variability in the growth of these tumors, whether irradiated or not. Occasionally, spontaneous rapid increase in size may occur in the later phases of growth of controls. "Diphasic growth," however, never was seen in control animals. The manner of regrowth in irradiated animals suggested that cells outside the irradiated zone are the source of the new growth. The lead shields protected this region from epilation and hence from much of the destructive effect of roentgen rays.

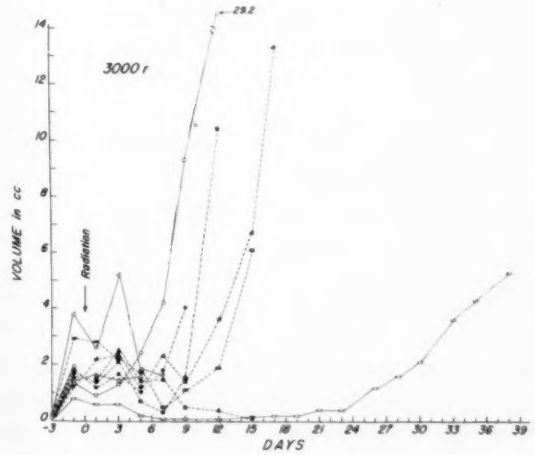

FIG. 17. Growth rate curves after dose of 3,000 r. Compare with previous growth rates. Note inhibition of growth and rapid regrowth in some cases (diphasic growth).

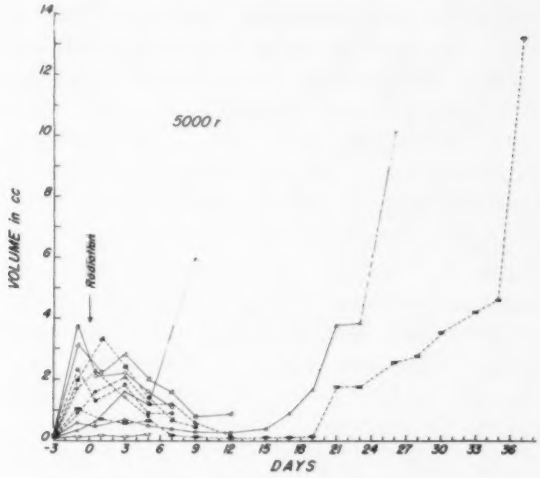

FIG. 18. Growth rate curves after single dose of 5,000 r. Growth is better inhibited, and regrowth occurs later with this dose than with 3,000 r.

4. What is the effect of irradiation of the isolated tumor? Under the usual conditions of the experiments, the presence of single cells or small cell mases outside the field of irradiation could not be eliminated. Another mode of therapy was therefore attempted. Small portions of the tumor were placed in glass dishes, and doses of 400 and 3,000 r administered. A control group of tumors were similarly manipulated, but did not receive irradiation. Portions of the controls and of the fully irradiated tumors were then placed subcutaneously into 10 mice for each dose level. Both the unirradiated controls and the tumors receiving 400 r grew in the usual fashion. There was *no* growth in animals transplanted with tumors which received 3,000 r.

Comment. In this experiment, there was

no doubt that the entire neoplasm received the full dose of radiation. The complete failure of growth in tumors receiving 3,000 r in a glass dish demonstrates that this dose is lethal for the glial cells. This indicates that irradiation of the bed of the tumor is not necessary to obtain lethal effects. Further, it suggests that the action of roentgen rays is directly on the tumor cells or stroma, and not by way of changes in the surrounding blood vessels. The findings offer additional support for the idea that the second part of the diphasic growth originates in cells protected against the full dose, because if the latter had been received, the cells would die. It is true that removal of the tumor from its subcutaneous bed at the time of irradiation makes conditions somewhat different from the other experiments, but the lethal quality of larger roentgen-ray doses is conclusively demonstrated.

5. Can diphasic growth be induced by protecting one-half of the tumor? It was thought that since regrowth of cells occurred in foci inadvertently not fully irradiated, such regrowth might occur more consistently by knowingly protecting a portion of the tumor. Ten animals, therefore, received 3,000 r after covering approximately one-half the tumor with a lead strip. Ten tumor-bearing animals served as controls and were not irradiated. In a few irradiated animals, there was a suggestion of a diphasic curve, but growth was never well inhibited. Some of the tumors grew just as well as in the control animals.

Comment. It is concluded that when only half of the tumor is irradiated, the remaining half may grow almost as if radiation had not been administered, but the response is variable and mild inhibition of growth may occur.

6. Can postirradiation regrowth be consistently produced by knowingly protecting a smaller portion of the tumor? To answer this question, groups of control and irradiated mice were handled in the usual fashion as outlined in "Methods" except that a small button of lead, the thickness of the chamber and one-eighth inch in diameter, was placed at one edge of the irradiated zone, thus covering a small part of the tumor. The dose was 3,000 r given to 12 mice, with 10 unirradiated control mice.

Of the 12 animals receiving 3,000 r, 3 showed rapid growth after decreasing in size. In the first 2 it occurred at about twenty days; in the third, at forty-five days. A massive increase in size was found. In addition, it should be noted that in none of these slightly protected animals was the tumor completely eliminated. This is contrary to what occurs in at least some animals when 3,000 r is administered without knowingly protecting the tumor.

Comment. It is clear that protection from the roentgen rays of a small number of cells is not adequate to increase significantly the number of animals exhibiting diphasic growth. It may still be said that unirradiated cells are necessary for the phenomenon to occur, but the conditions causing rapid growth cannot as yet be defined further. Failure to destroy completely any of these tumors indicates that even small portions of unirradiated neoplasm can regrow.

7. What is the effect of retransplantation of a rapidly growing tumor? Transplants were made into 20 mice from a single parent tumor of the previous series in the phase of rapid regrowth after receiving 3,000 r. The growth rate was that of the controls.

Comment. Retransplantation of a rapidly growing tumor does not result in rapid growth of the subtransplants.

DISCUSSION

There is great variability in the rates of growth of these gliogenous neoplasms in untreated animals. This is true even when the tumors are ground in a homogenizer, and similar numbers of tumor cells are delivered volumetrically to the site of transplantation.[17] Variability in growth occurs despite the use of genetically pure animals, and the existence of neoplasms which have been observed through many generations of

transplants, with histologic standardization. The rate of growth therefore cannot be correlated with the histologic appearance. This lack of correlation is noted under many other circumstances. It is apparent that there are unknown factors of growth inherent in the tumor, and unknown factors of host resistance, even in genetically pure strains of animals. How much more difficult is the problem in the genetically impure human being bearing unstandardized tumors, and without adequate control studies!

The results demonstrate that appropriate single doses of radiation have a growth-inhibiting and occasionally a lethal effect on these subcutaneously situated glial neoplasms. Small single doses of the order of a few hundred roentgen units do not stimulate growth nor do they inhibit the rate of growth. Evidence is presented that large doses (3,000 to 5,000 r) may be lethal if all the cells receive the rays. At these dose levels, destruction may be obtained without irradiating the tumor bed, suggesting that factors intrinsic in the tumor are responsible rather than changes in the surrounding blood vessels. Lorenz and Congdon[12] in a review of the biologic effects of ionizing radiations state "from a purely physical point of view, it seems hopeless to attempt to destroy a tumor by irradiation even if great differences in radiosensitivity exist between tumor and surrounding tissues. The physical reason for this is that the absorption process of radiation is of discrete nature, *i.e.*, not uniform. Therefore we cannot expect to kill each tumor cell even if large doses are given. Yet, it is known that a permanent regression of certain tumors can be obtained by irradiation. Radiologists stress the importance of the tumor bed in radiation therapy; and it is assumed that the effects of irradiation on the vascular supply of the tumor contributes in no small measure to the observed regression of many neoplasms." The present experiments offer evidence against the role of the tumor bed, and fail to support the idea that vascular changes in the tumor play a significant role in destroying a glial neoplasm.

If complete destruction was not effected, rapid regrowth sometimes followed the initial inhibition ("diphasic growth"). The rapid growth in the second phase suggests that roentgen rays or their secondary effects may accelerate growth. The time of appearance of the second phase varied in different animals, and attempts to produce it more often were not successful. A diphasic response was obtained by Lucke and Schlumberger[13] following treatment with single doses of 2,000 r to a frog renal adenocarcinoma.

The following facts are known of the mechanism of the diphasic response in our experiments. First, the histologic appearance of these tumors is not different from the controls. This means that a biologic phenomenon does not have a histologic counterpart. Second, retransplantation of rapidly growing tumors into unirradiated animals does not result in continued rapid growth. This means that the responsible factors are present only when there is a combination of irradiated tissue and irradiated tumor bed. Third, protection of a small part of the tumor is not always effective in producing rapid regrowth. This cannot be easily explained, but a tentative hypothesis may be offered.

Loofbourow[11] has shown that cell-free suspension media from radiation (ultraviolet) damaged yeast cells may stimulate growth of normal yeast cells. His experiments indicate that when yeasts are damaged by radiation the chemical changes in the suspension media are quite complex. There are increases in the concentration of amino acids, vitamin B complex, nucleotides and nucleosides. The largest increases were in pantothenic acid and folic acid, and thereafter in nucleotides and riboflavin.

As a tentative explanation of the diphasic growth curve, it is suggested that a growth promoting x material from heavily irradiated cells must interact with slightly irradiated or unirradiated cells. If the number of the latter is too great, the effect of x is prevented. Growth is temporarily inhibited by radiation, most of the cells in the

field are altered and die, but they release growth-promoting substances which can act only on a small number of nearby cells because of the low concentration of *x*. When the proportion of irradiated and unirradiated cells is the proper one, rapid increase in size of tumor is initiated, and the animal soon dies.

The results of these animal experiments raise some interesting problems in the treatment of human gliomas. The numerous contradictory reports on this subject, and the variable responses even in the hands of a single individual may have many bases. One factor may be the inherent variability in rate of growth of members of a given histologic group. Frazier and Alpers[8] suggested that medulloblastomas might not be a homogeneous group of tumors. This could apply to all types of gliomas. Furthermore, since the full extent of the tumor is rarely known in man, the neoplasm may not be fully irradiated with the recorded dose. It is suggested that if even small portions of the tumor are not irradiated they may serve as a nidus for regrowth. The pleomorphism of many human gliomas has been discussed and presents another basis for variability in response.

Whether irradiation stimulates the growth of human gliomas is not easily answered. The natural history of these tumors is variable[19] and, as outlined at the beginning of the report, interpretation of changes in the course is difficult. Tarlov[22] raised the possibility that some human gliomas "may become less differentiated and more rapidly growing after irradiation."

The lack of correlation between biologic behavior (rates of growth) and the appearance of the tumor as seen histologically is noted during normal growth, after irradiation, and in the period of regrowth. The best histologic correlation is with the immediate effect of radiation, but these differences become less apparent as time elapses after administration of ionizing radiation. It should be noted that in man there is a similar discrepancy.[1,6] Those workers who have investigated the problem have commented on the lack of proportion between histologic effects and the amount of radiation.

The effect of roentgen rays on the blood vessels of cerebral tissue has been debated in the past. A principal effect on blood vessels has been found by some,[14] and little effect on vessels by others.[5] More recent evidence[2] is more in accord with the latter idea.

The histologic changes in human gliomas as a result of irradiation have been reported by a few workers.[1,6,22] These studies necessarily have been limited in extent. In general, it is agreed that medulloblastoma is the most sensitive and oligodendroglioma the least sensitive as judged by histologic response. There is lack of agreement concerning the responses of glioblastoma multiforme, ependymoma, and astrocytoma. All workers are agreed that individual cases of a presumably sensitive neoplasm may show no changes attributable to the roentgen rays. These general statements are similar to the results obtained clinically, but there is little correlation in an individual case between histologic changes and clinical results.

The usual histologic findings were alterations of the tumor cells and increase in the amount of connective tissue stroma. The blood vessels may become thickened or undergo proliferation, but this has not been reported with the same frequency, nor is it apparently as important in gliomas as in tumors occurring elsewhere in the body. The regression of irradiated neoplasms in general has been thought to be dependent on changes in blood vessels as well as on destruction of tumor cells.[23] On the other hand, Deery[6] thought the vascular changes in gliomas were secondary and incidental, and Tarlov[22] found vascular changes in very few of his 26 cases. Focal zones of necrosis may be interpreted as the result of outgrowing or impairment of the blood supply, but our findings did not support this contention. The blood vessels in necrotic foci, spontaneous or radiation-induced, were thin-walled, patent, and were

present in numbers comparable to those of viable tumor. In this connection it should be noted that evidence is available that anoxia is correlated with radioresistance, and hyperoxia with tumor regression.[12] These data suggest again that the action of roentgen rays on gliomas is primarily on the tumor itself and that vascular changes are at best a secondary phenomenon.

SUMMARY AND CONCLUSION

A critical review is presented of the data on treatment of human gliomas with roentgen therapy. The difficulties in determining the value of such treatment are emphasized.

The effect of single doses of roentgen rays on experimentally induced gliomas is discussed. Doses ranged from 200 r to 5,000 r. Histologic alterations were detected at the lowest level, but these were minimal and transient. Alterations in the appearance of the tumor at the higher levels were striking. Vascular alterations were not a prominent part of the change.

There was wide variability in the rates of growth of unirradiated tumors. Studies of the rate of growth of irradiated tumors showed that small doses did not cause stimulation of growth; intermediate doses caused a transient depression of growth; and high doses either destroyed the tumor or resulted in "diphasic growth." The latter term refers to regrowth after initial inhibition of size of the tumor. On occasion, such regrowth was extraordinarily rapid. Attempts to increase the incidence of rapid regrowth were not successful. Evidence is presented that rapid regrowth is initiated in cells just outside the irradiated zone. A hypothesis is presented to explain this phenomenon. It carries the implication that inadequate or incomplete roentgen treatment is dangerous because growth may be stimulated.

Correlation of histologic changes with biologic activity and effects is generally poor. The best correlation was obtained by comparing the different sizes of roentgen dosage, and the sequence of changes in the first few weeks after therapy. Under other conditions and at other times, the microscopic appearance was a poor means of judging what had happened in the past or was occurring presently in the neoplasm.

Evidence is discussed which minimizes the role of blood vessels and of irradiation of the tumor bed in the mechanism of roentgen-ray damage and the production of foci of necrosis. The effect of roentgen rays is believed to be directly on the neoplasm.

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RADIOACTIVE GOLD IN THE SUBARACHNOID SPACE OF THE DOG

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THIS investigation was made to determine whether a suitable isotope could replace external roentgen irradiation in treating medulloblastoma. Because this tumor characteristically seeds itself along the subarachnoid space, irradiation of the entire length of the spinal cord is an accepted therapeutic procedure. Since experience with radioactive isotopes in the subarachnoid space is not recorded in the literature, it was decided to experiment with radioactive gold in a dog to determine its safety and efficacy. Radioactive gold was chosen for the following reasons:

1. Au^{198} in colloidal suspension, with or without saline, can be made to diffuse homogeneously throughout a cavity. This has been amply demonstrated by the instillation of gold in pleural and peritoneal spaces.

2. Au^{198} in its disintegration emits a beta ray of 0.98 mev. and two gamma rays of 0.12 mev. and 0.41 mev. The best estimate is that 95 per cent of the radiation is contributed by the beta-ray component which has a maximum range of 3.8 mm. in water. Therefore, irradiation might be obtained throughout the subarachnoid space while avoiding unnecessary irradiation of the spinal cord, vertebral column, soft tissues and skin of the back.

TECHNIQUE

A 10 kilogram dog was anesthesized with nembutal. The lower back was shaved, prepared with usual antiseptic precautions, and a spinal tap was done at the level of L_3–L_4. After removal of 2 cc. of clear spinal fluid, a solution containing 6.6 millicuries of Au^{198} in 2 cc. of sterile water was injected into the subarachnoid space. The dog was tilted back and forth in see-saw fashion for ten minutes to promote uniform distribution of the gold.

CLINICAL OBSERVATIONS

The dog was observed daily for a period of thirty-eight days. During the first fourteen days the animal showed extreme irritability, characterized by shrinking away and biting at the hand whenever food was offered. There was no apparent change in bowel or bladder function. He ate regularly without vomiting and showed no signs of ataxia while walking about the cage. There was a progressive decrease in irritability so that by the fourteenth day he was friendly and permitted stroking and play. At this time, crude neurological tests were permissible and the anterior limbs showed active and symmetrical "knee jerk" responses. Thereafter, the course was uneventful and the dog behaved normally.

On the thirty-eighth day after gold injection, the dog was sacrificed. After nembutal induced anesthesia, a thoracotomy was done and a 10 per cent solution of normal saline was injected into the ascending aorta. The dog died during this injection.

A necropsy was immediately performed, and the brain and spinal cord were removed from their bony encasement after the membranes were opened and nerve roots sectioned. No gross abnormality of the brain, spinal cord, liver, spleen or kidneys were noted. The specimens were placed in formaldehyde.

PHYSICAL MEASUREMENTS AND DOSAGE

During the investigation, readings were taken with a Thyac survey meter. At the

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TABLE I

READINGS AT TIME OF INJECTION

Site	Rate, mr/hr.
Cauda equina	0.16
Lower lumbar spine (site of injection)	0.14
Upper lumbar spine	0.11
Mid dorsal spine	0.075
Lower cervical spine	0.05
Cisterna magna	0.025

time of injection of Au^{198}, the irradiation was so intense that measurements were made at a distance of 10 cm. from the skin over the spine. Subsequent measurements during the life of the dog were taken at the same distance. The meter was calibrated to read in milliroentgens per hour (see Tables I to IV).

The dosage given to the area encompassed by the subarachnoid space surrounding the spinal cord was calculated according to the formulae of Glasser, Quimby, Taylor and Weatherwax. Separate calculations were made for dosage contributions from beta and gamma activity. Assuming that distribution of radioactivity approaches homogeneity throughout the volume treated and that none of the Au^{198} escapes into the general circulation, these formulae are applicable. The length of the spinal cord was 75 cm., the average cross section diameter 0.8 cm., and the volume, therefore, was estimated to be 37.5 cc.

TABLE II

READINGS FOUR DAYS AFTER INJECTION

Site	Rate, mr/hr.
Lumbar spine	0.05
Dorsal spine	0.03

TABLE III

READINGS TWELVE DAYS AFTER INJECTION

Site	Rate, mr/hr.
Site of injection	0.01
Upper lumbar spine	0.007
Cervical spine	0.002

TABLE IV

READINGS TAKEN AT NECROPSY WITH THE METER DIRECTLY AGAINST THE SPINAL CORD

Site	Rate, mr/hr.
Site of injection	0.02
Dorsal spine	0.012
Cervical spine	0.012
Cisterna magna	0.012

Dosage beta in rep/μc./gm. = c × 88 × E × T in which

c = concentration

E = average beta energy in mev.

T = half-life

$$\frac{6600}{37.5} \times 88 \times 0.32 \times 2.7 = 13{,}332 \text{ rep}/\mu\text{c./gm.}$$

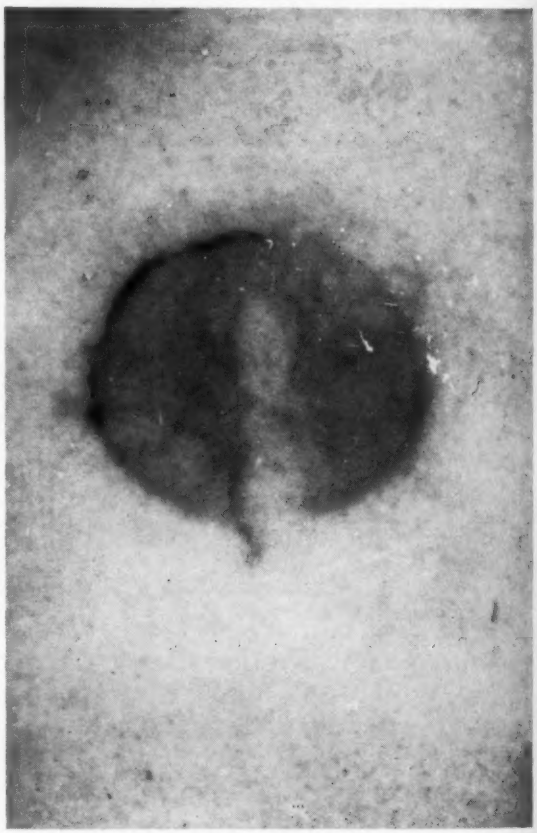

FIG. 1. Radioautograph of the lumbar spinal cord showing uniform distribution of radioactivity from Au^{198} in the white and gray matter of the cord with heavy concentration in the pia.

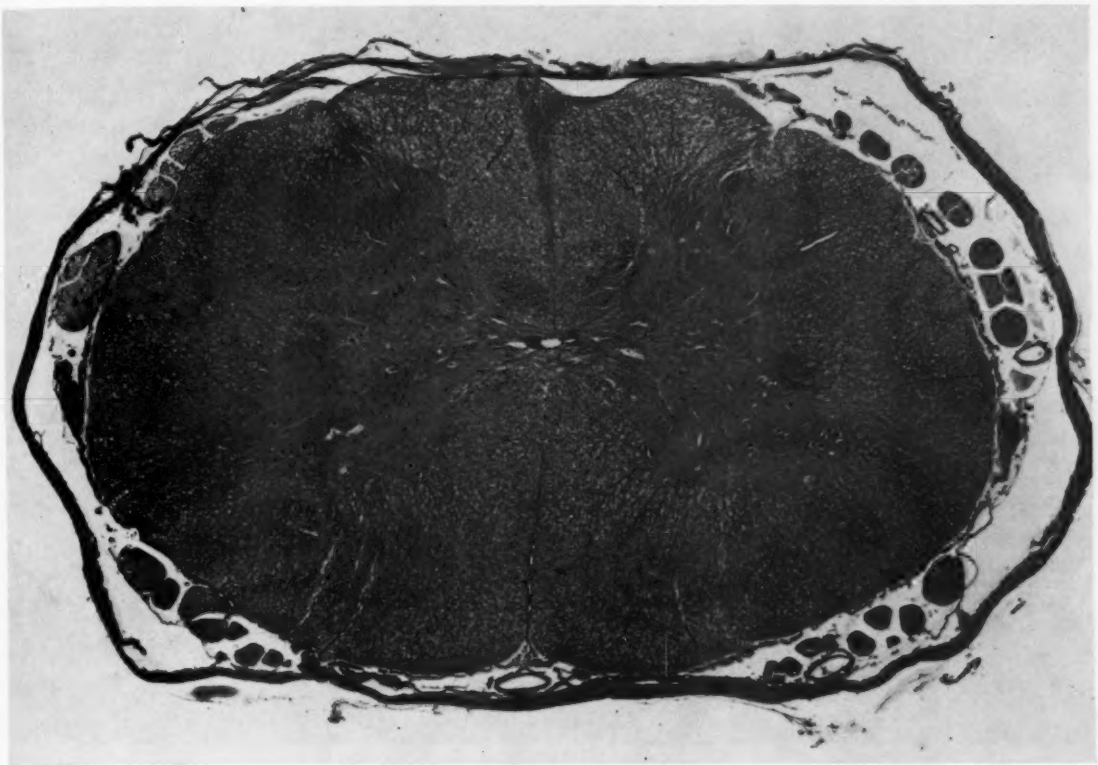

Fig. 2. Low power section of the lumbar spinal cord showing absence of inflammatory or radiation changes.

Dosage gamma in rep/μc./gm. = C×g×K× gamma in which

C = concentration

K = r/μc./at 1 cm.

g = geometric factor 27

$$\frac{6600}{37.5} \times 27 \times 0.22 = 1047 \text{ r}/\mu\text{c}.$$

RADIOAUTOGRAPHY

The day after necropsy or forty days after instillation of the Au^{198}, frozen sections were cut from all levels of the spinal cord. These sections of 20 microns thickness were floated in saline onto slides and allowed to air dry. They were mounted with pressure against high speed roentgen films which were developed at four weeks and six weeks. These intervals were chosen because negligible radiation remained at 14 half-lives of the gold.

The films revealed no radioactivity in the cervical and upper dorsal segments. Mild blackening of the film was seen in the mid dorsal and lower lumbar sections, but greatest blackening was recorded at the section taken from the site of injection (Fig. 1). This section showed homogeneous activity throughout the cord with heavier activity at the periphery corresponding to the pia.

HISTOPATHOLOGY

Sections taken from all levels of the spinal cord were stained by the various techniques used in neurohistology. Dr. Lewis Stevenson, Visiting Neuropathologist, Bellevue Hospital, New York, reviewed the slides (Fig. 2, 3 and 4). Sections stained for myelin revealed swelling of myelin sheaths at all levels of the cord, probably because of paraffin fixation of the sections. At the level of the injection in the anterior lateral column, there was a spongy state which is the type of lesion one sees above and below the site of injury to the

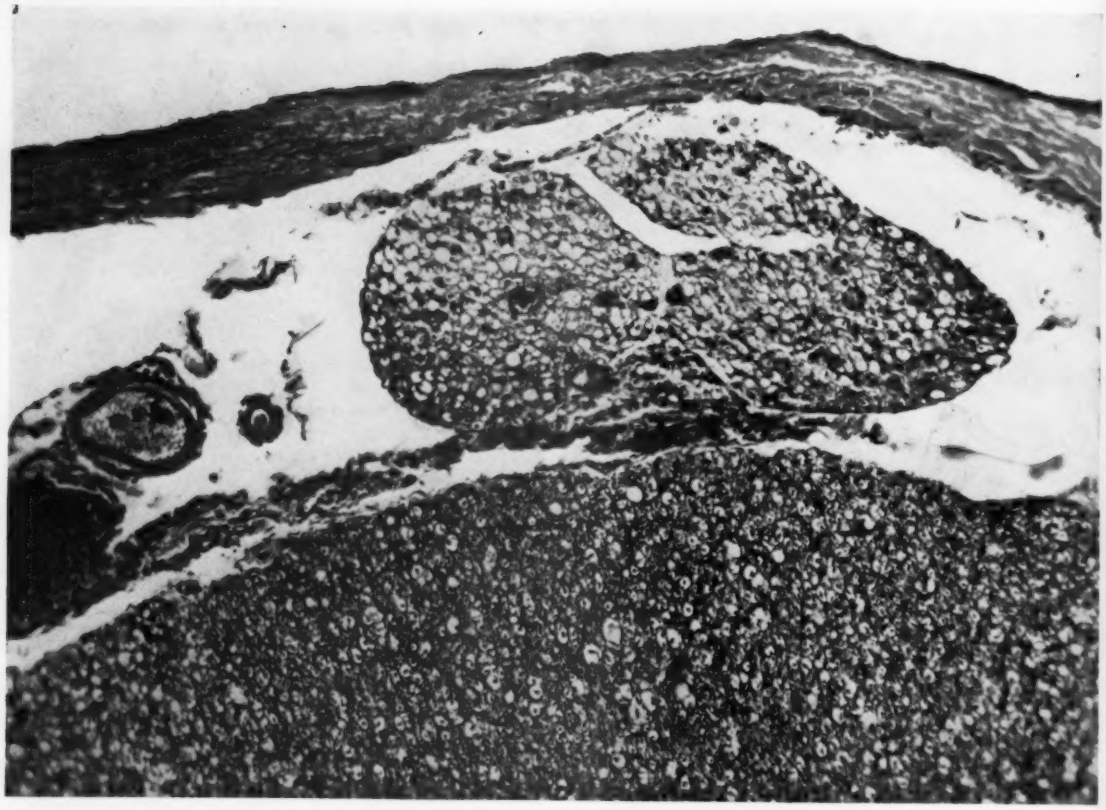

FIG. 3. High power view of the lumbar spinal cord and meninges showing the absence of acute or chronic radiation or inflammatory changes in the pia, arachnoid and dura, blood vessels and white matter of the cord.

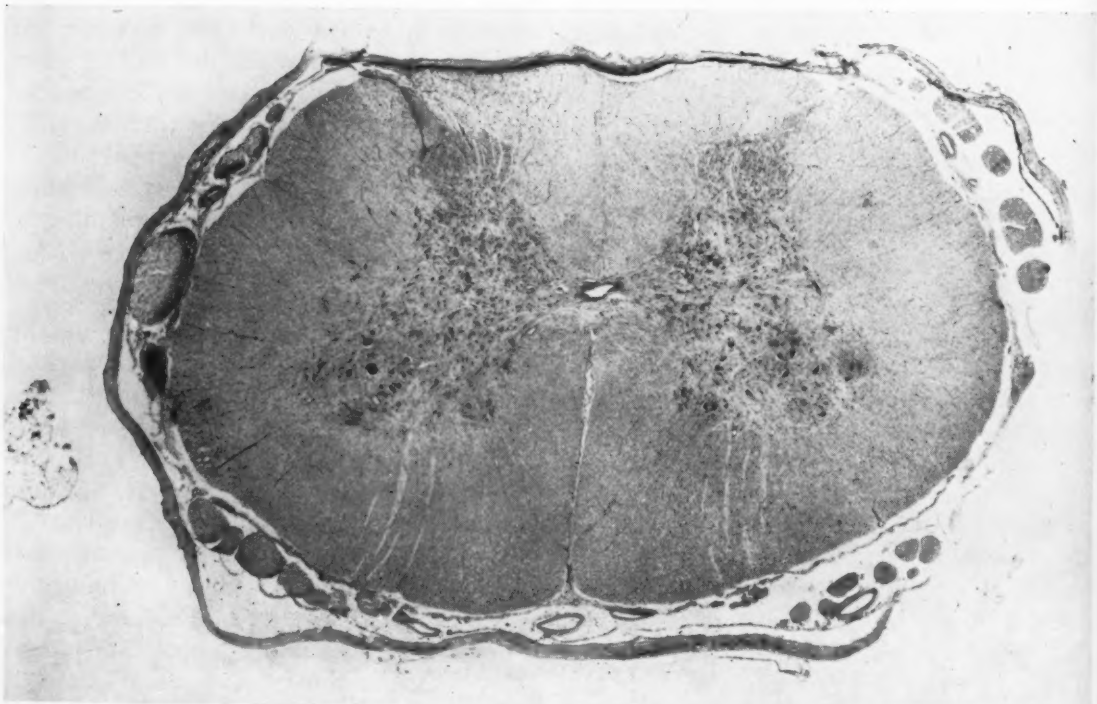

FIG. 4. Low power section of the dorsal spinal cord showing normal white and gray matter, blood vessels and meninges.

cord. This change could have been caused by needle puncture.

Sections with Mallory stain revealed normal meninges. No thickening of pia or arachnoid membranes and no conspicuous thickening of blood vessels were noted.

Nissl's staining method revealed no absence of cells or conspicuous dropping out of cells. The cells generally appeared to be normal with slight atrophy in many areas, thought to be the result of shrinkage after fixation in alcohol and paraffin.

Hematoxylin and eosin stained sections revealed no evidence of inflammation of the cord or meninges.

Hematoxylin and eosin stained sections of liver, kidney and spleen revealed normal histology.

CONCLUSIONS

1. Six and six-tenths millicuries of Au^{198} injected into the subarachnoid space of a dog were well tolerated. Calculated dosages of 13,332 rep/μc./gm. of beta activity and 1045 r/μc. of gamma activity were in excess of therapeutic dose levels used in man.

2. Activity was fairly uniform in the lumbar and dorsal regions.

3. Radioautographs revealed evidence of radioactivity in the cord at the lumbar and mid dorsal segments.

4. Histopathologically, there was no evidence of acute or chronic radiation injury to the cord and meninges.

5. Since radioactivity was detected in the cord by radioautography, and in view of the absence of pathological findings, this investigation in one animal is inconclusive.

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ENERGY DEPOSITION IN TISSUE BY NEUTRONS OF VARIOUS ENERGIES AND THE B^{10} (n, α) Li REACTION

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CURRENT work by Farr, *et al.*,[1,2] and others[3,9] have reactivated interest in the possibility of treating neoplasms[4,12] by use of "boron disintegration therapy." When B^{10} captures a thermal neutron, energetic alpha and lithium particles are released. If the B^{10} atoms can be differentially localized in tumors in significant amounts, the energy of the alpha and lithium particles would be dissipated completely within microns of the location of the B^{10}. Thus, if sufficient B^{10} were concentrated in a neoplasm, which would then be irradiated by thermal neutrons, the tumor might be destroyed without irreparable damage to the surrounding tissue.

Recently[3,9] an investigation was made of the uptake of B^{10} by tumor tissue and normal brain tissue, after the intravenous injection of 15 g. borax/70 kg. body weight into patients with intracranial tumors. In typical cases there was an uptake of 50 μg. B^{10}/g. of tissue. The peak ratios were usually present only during the first fifteen to thirty minutes after injection.

Farr, *et al.*[1,2] treated ten patients, who were irradiated with thermal neutrons at the Brookhaven reactor. The results obtained to date "were encouraging clinically but were far from definitive." Ten patients in this series had received the B^{10} in the form of borax injected intravenously. A new series of patients will be treated in the near future. Recently Kruger,[5] working with brain tumors in mice, showed that boron, injected in the form of certain dyes, was taken up most strongly in the growing edge of the tumor. Using the dye technique he found approximately thirty times as much boron/cm.^{3} appearing in the tumor relative to healthy tissue, as compared with the case in which borax was used as the vehicle for the boron.

In order to evaluate the possible clinical usefulness of the method described above, it is necessary to estimate the dosage rate in tumor tissue and the "background" dosage rate in healthy tissue. It is the ratio of these two quantities that is the important parameter. This calculation permits one to set minimum values for B^{10} concentration in the lesion (during the period of irradiation by a thermal neutron beam), to achieve a desired ratio of tumor dose to healthy tissue dose. Additionally, upper limits may be set to the fraction of a neutron beam that may consist of nonthermal neutrons; similar upper limits may be set for the degree of gamma ray contamination that may be tolerated. These criteria for the composition of a beam suitable for therapy may be utilized in designing a reactor that will have therapy applications as its chief function.

The dosage rate in tumor tissue will depend on the B^{10} concentration in the tumor tissue and on the value of the thermal flux at that site. The dosage rate in healthy tissue will arise from a number of sources which include: (1) Direct effect of gamma rays contaminating the neutron beam; (2) direct effect of slow, intermediate energy and fast neutrons on healthy tissue; (3) effect due to presence of B^{10} in healthy tissue.

Calculations of energy deposition in tissue by neutrons of various energies have been made by Tait[10,11] and others.[8] The estimates made in the present report (Table II) are based on Tait's curves. He calculates the thermal neutron distribution produced in a semi-infinite medium (by intermediate energy neutrons entering normally to its free surface) by using a two group diffusion theory. In his estimation of the effect of fast neutrons, he deter-

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Table I

Agent	Physical Process
1. Thermal neutrons	Capture of neutrons by tissue H* and N as follows: H(n, γ)D: γ energy = 2.2 mev. N(n, p)C: proton energy = 0.61 mev.
2. Intermediate energy neutrons (up to 100 kev.)	Capture processes listed above; also transfer of neutron's kinetic energy by "billiard ball" type of collision (mostly to H in tissue)
3. Fast neutrons	Kinetic energy transfer to H in tissue
4. B^{10} in tissue plus thermal neutrons	Capture process: B^{10} (n, α) Li^7; alpha energy = 1.47 mev. lithium energy = 0.84 mev. } 93% gamma ray† = 0.48 mev. alpha energy = 1.78 mev. lithium energy = 1.01 mev. } 7%

* It has been shown by Javid[3] *et al.* that the contribution of elements in the body other than H and N is very small and may be neglected.

† The contribution to the tissue dosage of the gamma ray component of the B^{10} capture disintegration process is quite small compared to that due to the direct neutron effect.

mines the distribution of the energy flux in the "semi-infinite tissue" by using a spherical harmonics method. An estimate was made of the effect of the B^{10} on the thermal flux and it was found to be small. There is an uncertainty of perhaps 20 per cent in Tait's estimates[11] of the thermal flux distributions because of an uncertainty in the choice of the proper value of a transport mean free path for the past groups (due to a variation of the cross section with energy).

The energy deposition both in the tumor and healthy tissues will arise mainly from the sources shown in Table I (neglecting the direct effect of the gamma rays).

The effectiveness or efficiency with which biologic tissue is damaged depends on whether a heavy particle or a gamma or *x*-ray photon is the primary cause of ionization. This efficiency factor, called the relative biologic efficiency or RBE, depends to some extent on the kind of tissue involved and on whether or not the ionizing agent is in the cell or in the nucleus. The effect arises basically because of the increased linear ionization density due to the passage of a heavy charged particle as compared with the ionization track caused by passage of a gamma ray photon. This report will not analyze which is the best value of the RBE to use. Instead, the numbers are meant to be illustrative; additionally, the ratio of the tumor tissue dose to healthy tissue dose does not depend sensitively on the exact value of the RBE, since it turns out that most of the effects arise from heavy particle ionization processes. A representative value of the RBE = 20[6,11] is used in Table II. The dosage rate unit employed is the rep/min. × RBE, where the rep is defined as the dose delivered when the tissue absorbs 93 erg/g. For convenience rep/min. × RBE will be called reb/min. (or roentgen equivalent biological/min.) (see ref. 3). Table II lists the dosage rates (in reb/min.) at various depths in tissue due to the various processes listed in Table I for incident unit flux of neutrons (1 n/cm.^{2}-sec.) on the skin (as measured by a thin detector without the patient). The doses at depths of 2 to 4 cm. below the surface are particularly important since critical tissue (blood forming organs) may be located there.[7,11] The dosage rate in reb/min. due to the B^{10} (n, α) Li^7 reaction is computed as:

$$\frac{\phi \times \Sigma_{ab} \times 60 \times E \times 10^6 \times \eta}{5.8 \times 10^{13} \text{ (ev./cc./per rep)}}$$

where:

ϕ is the thermal flux in n/cm^2-sec. (the effect of the B^{10} on ϕ is not taken into

TABLE II

Agent	Process	Dosage Rate in (reb/min.) $\times 10^9$ for unit incident flux and at following depths into tissue			
		Surface	1 cm.	2 cm.	4 cm.
1. Thermal neutrons	H(n, γ)D	27	31	29	23
	N(n, p)C	58	75	54	25
		85	106	83	48
2. 10 ev. neutrons	H(n, γ)D	19	23	23	19
	N(n, p)C	15	44	50	42
	transfer of kinetic energy	0.15			
		34	67	73	61
3. 1.0 kev. neutrons	H(n, γ)D	31			
	N(n, p)C				
	transfer of kinetic energy	15			
		46			
4. 10 kev. neutrons	H(n, γ)D plus N(n, p)C	27	50	60	54
	transfer of kinetic energy	14		44	
		41		104	
5. 100 kev. neutrons	H(n, γ)D plus N(n, p)C	27	52	67	64
	transfer of kinetic energy	1,000	690	440	150
		1,000	740	500	210
6. 0.5 mev. neutrons	transfer of kinetic energy	2,600	2,200	1,700	940
7. 1.0 mev. neutrons	transfer of kinetic energy	3,300	3,000	2,800	2,000
8. 2.0 mev. neutrons	transfer of kinetic energy	4,600	4,300	4,000	3,500
9. B^{10} in tumor tissue with 50 μg. B^{10}/g. tumor tissue	$B^{10}(n, \alpha)Li^7$	1,500	1,700	1,200	620
10. B^{10} in healthy tissue with 12 μg. B^{10}/g. healthy tissue	$B^{10}(n, \alpha)Li^7$	360	410	280	150

account) at the depth indicated due to unit incident flux on the skin, following Tait.[11]

$\Sigma_{ab} = 3900\, N_{B^{10}}$ is the macroscopic cross-section for capture of thermal neutrons by B^{10} nuclei

$N_{B^{10}}$ is the number of B^{10} atoms present per cm.^{3}

E is the combined energy of the α and Li^7 particles = 2.35 mev.

η is the RBE = 20

Items 9 and 10 of Table II are computed on the basis of the estimated flux at the given depth and on the assumption that the tumor (with the stated B^{10} content) is located at that depth.

It is apparent from the table that a fast neutron (as typified by 2 mev.) is some 50 times as effective as a thermal neutron in producing damage; a 100 kev. neutron is only about 5 to 10 times as effective as a thermal neutron, depending on the depth of interest. At 2 cm. the ratio is about 6 to 1. Thus if the total integrated fast flux is less than 1 per cent of the thermal flux, then the effect due to fast neutrons will not be important. In the case for which Table II was computed, the energy deposition is controlled largely, both in the healthy and tumor tissue, by the site of the B^{10} atoms (provided the integrated fast flux is small compared to the thermal flux).

For neutrons of energy less than 1 kev. the dose due to transfer of kinetic energy to protons is unimportant.

If suitable techniques are developed for localizing the B^{10} in the tumor tissue, and the ratio of integrated fast flux to thermal flux is controlled, then the energy delivered to the normal tissue would be quite small compared to that delivered to the tumor site. If the healthy tissue dose were due only to direct effects of the thermal and fast neutrons, then it might be possible to obtain a ratio of tumor dose to healthy tissue dose of the order of 10 to 15 to 1 in a single port treatment. This ratio compares very favorably with other known methods of administering radiation therapy. If the tumor site is at a great depth, say 10 cm., the tumor dose would be about the same (assuming a diminution of thermal flux by factor 2 for each 2 cm. depth), as the near surface dose due to thermal neutrons; if larger amounts of B^{10} can be delivered to the tumor site, the tumor dose is correspondingly increased. This situation still compares favorably with the ratio of conventional therapy depth dose to near skin dose of about 60 per cent. For deep-seated lesions rotational terapy technique might again raise the ratio of tumor to near surface dose to approximately 15 to 1. Of course, this latter method involves the exposure to radiation of larger amounts of healthy tissue at a lower integrated flux.

The quite different values for the dosage rates in Table II and those quoted in reference 3 are due to the different values of RBE used, and also to the back-scattering effect of the body on near surface dosages. (This latter factor alone is approximately 2.)

SUMMARY

A comparison is made of the energy deposition in tissue due to "boron disintegration therapy" with the background dosage in healthy tissue due to direct effects of thermal, intermediate energy and fast neutrons. Minimum values of B^{10} concentration in a lesion are obtained that will lead to a desired ratio of tumor dose to healthy tissue does. Upper limits are set to the fraction of a neutron beam that may consist of non-thermal neutrons.

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POSSIBLE USE OF THE NEUTRON CAPTURING ISOTOPE LITHIUM^6 IN THE RADIATION THERAPY OF BRAIN TUMORS*

By ALFRED J. LUESSENHOP, M.D.,† WILLIAM H. SWEET, M.D., *and* JANETTE ROBINSON, A.B.

THE treatment of tumors by irradiation with alpha particles arising within the tumor itself, which has progressed to therapeutic trials in man, involves physical principles unfamiliar to many biologists. We summarize these herewith.

Most of the subnuclear radiations and particles interact in a relatively nonspecific fashion with whatever atom they encounter. Thus gamma rays, beta and alpha particles, protons and fast neutrons are usually produced at radioactive decay with large energies ranging up into the millions of electron volts (mev.). The net result of the interaction with matter of such rays and particles at these high energies is the displacement of orbital electrons ionizing the remaining atom. This type of ionization has a potentially lethal effect on living tissue, to be distinguished from the ionization of electrolytes in solution.

However, when the speed of a neutron is reduced to so-called thermal levels (2,200 meters/sec., leaving it with an energy of only .025 electron volts, ev.), this energy is far below the circa 10 ev. required to displace an orbital electron. Neutrons at such low energies react with atoms in an entirely different way, *i.e.:* with the nucleus rather than the orbital electron, and the nuclei of a certain few isotopes react far more avidly than the great majority of the atomic types comprising matter. That is to say, the reaction has great isotopic specificity.

This reaction which consists literally of capture of the neutron by the nucleus results in a new compound nucleus with an excess of energy, which is immediately given up in one of two major ways resulting either: (1) in instantaneous release of all the energy or (2) in a more protracted release as a consequence of the appearance of a radioactive daughter.

In the first situation there emerges a stable isotope and a "capture radiation"—gamma ray or heavy particle.

$$\textit{E.g.,}\ \text{Hydrogen}^1 + \overset{\text{thermal}}{\underset{\text{neutron}}{}} \rightarrow (\text{hydrogen}^2) \rightarrow \text{hydrogen}^2 + \text{gamma ray}$$

( ) is symbol for unstable compound nucleus

$$H^1 + n_{th} \rightarrow (H^2) \rightarrow H^2 + \gamma \text{ ray (2.23 mev.)}$$

$$\text{Boron}^{10} + \overset{\text{thermal}}{\underset{\text{neutron}}{}} \rightarrow (\text{boron}^{11}) \rightarrow \text{lithium}^7 + \text{alpha particle}$$

$$B^{10} + n_{th} \rightarrow (B^{11}) \rightarrow Li^7 + \alpha^{++} (2.4 \text{ mev.})$$

$$\text{Lithium}^6 + \overset{\text{thermal}}{\underset{\text{neutron}}{}} \rightarrow (\text{lithium}^7) \rightarrow \text{hydrogen}^3 + \text{alpha particle}$$

$$Li^6 + n_{th} \rightarrow (Li^7) \rightarrow H^3 + \alpha^{++} \text{ (4.6 mev.)}$$

In the second situation there emerges a radioactive daughter isotope which goes on emitting a further radiation at its characteristic rate and a "capture radiation," in the example below, a proton.

$$\text{Nitrogen}^{14} + \overset{\text{thermal}}{\underset{\text{neutron}}{}} (\text{nitrogen}^{15})$$

$$\rightarrow \text{proton} + \text{carbon}^{14} \text{ (half life 5,700 years)}$$

$$\rightarrow \text{nitrogen}^{14} + \text{electron}$$

$$N^{14} + n_{th} \rightarrow (N^{15}) \rightarrow p^+ + C^{14} \rightarrow N^{14} + \beta^-$$

The avidity of each isotope for capture absorption of slow neutrons has been measured precisely in terms of its so-called capture or absorption cross section, σ_a. This is the apparent area in cm.^{2} presented by a single nucleus of the element to the incident beam of such neutrons. The term for the unit is the "barn" $\times 10^{-24}$ cm.^{2}. This arose from the facetious, but

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appropriate, idea that in relation to the size of the nucleus a cross section of 10^{-24} cm.^{2} was proportionally as big as a barn.

Fortunately, the σ_a, the capture capacity, of the atoms normally present in animal tissue is uniformly low, ranging from <.001 for O^{16} to 32.5 for Cl^{35}. In contrast a tiny number of all the known isotopes possess extraordinary capacity for such capture. The σ_a for the isotopes in this group follow: Li^6—870, B^{10}—3,900, Cd^{113}—24,000, Sa^{149}—46,000, Eu^{155}—14,000, Gd^{157}—200,000, Dy^{164}—2,620, Hg^{199}—2,500. Of these, the isotopes Li^6 and B^{10} are the only ones whose capture reaction emits an alpha particle. The great relative weight of this particle precludes its travel in tissue more than 40μ even when emitted at 4.6 mev. as in the case of the Li^6 reaction. This means that the destructive effect is confined to the immediate vicinity of the cell containing or adjoining the isotope in the cases of Li^6 and B^{10}.

In 1940 Kruger[12] first directed attention to the possible use of a neutron capturing agent such as boron[10] for creating an increased localized radiation effect. *In vitro* he exposed various rat neoplasms soaked in buffered boric acid solution to a flux of thermal neutrons and found a decreased percentage of takes following transplantation. That same year Zahl, Cooper and Dunning[26] described *in vivo* experiments utilizing the same principles, but employing Li^6 as well as B^{10} as the neutron capturing agent. Lithium metaborate in oil was injected into the tumors of mice bearing sarcoma 180 and the animals subjected to ten hours of thermal neutron bombardment. Regression of growth of the tumors was observed. And by comparing the known effects of roentgen rays, Zahl, Cooper and Dunning calculated that the tumor received 750 to 1,000 roentgens whereas the whole body dose was only 400 roentgens. Thus they concluded, as Kruger had previously, that an increased localized radiation effect was due to the presence of the neutron capturing agent at the tumor site. The following year Zahl and Cooper[27] described further experiments in which they endeavored to obtain a more uniform distribution of the neutron capturing agent in the tumor. To mice bearing sarcoma 180, they administered intravenously lithium combined with various acid dyes and as lithium chloride. Although the dyes tended to concentrate preferentially in the tumor, the lithium-dye combination offered little advantage over administration of the chloride salt because there was a dissociation of lithium and the dye *in vivo*. Hence they did not succeed in producing a significantly high concentration of the lithium in tumor as compared with the normal visceral tissues they studied. The concept also lay fallow because of an inadequate source of thermal neutrons to irradiate tumors. But with the advent of the nuclear reactor, Conger and Giles[6] (1950) studied the effect of the neutron beam in lily bulbs and computed that most of the radiation damage was attributable to the trace amounts of boron contained normally in such plants.

These careful observations and computations led Sweet and Javid[22] to study the feasibility of employing B^{10} in the radiation therapy of brain tumors. They found (1952) that B^{10}, as a borax compound, given intravenously to patients undergoing craniotomy, concentrated in glioblastomatous tumors at an average of somewhat greater than 3 to 1 over normal brain for a period of 30 to 45 minutes following injection. Previously Zahl's efforts had been directed toward finding a method of increasing specifically the concentration of the agent in tumors as compared with other tissues in general. In contrast the differential concentration in brain tumors over normal brain depends not so much upon an increased uptake by the tumor but rather upon a decreased uptake in the surrounding normal brain contrasted with the other normal tissues. This is a result of the normal operation of the blood brain barrier. That such barrier function is absent in the substance of brain tumors is now a well established observation.[14,20,23]

In a second paper in 1952 Javid, Brownell and Sweet[11] presented an estimation of the radiation energies that would be derived

from such a differential concentration of B^{10}. Their results confirmed that the locus of the B^{10} atom would be the chief determinant for evolved radiation energy and at a differential concentration of 3.3 to 1, the radiation effect in the tumor would be 3 times that in normal brain, provided there was a uniform flux of thermal neutrons.

Since this last publication, 10 patients, from our service, with glioblastoma multiforme have been treated by neutron capture utilizing boron[10] at the Brookhaven National Laboratory in Long Island. The results of this have recently been reported by Farr, *et al.*[9] and Godwin, *et al.*[10] The principal difficulty encountered was the inability to obtain sufficiently high radiation energy at the tumor site. The treatment portal at the nuclear reactor has been redesigned and rebuilt and we have now, in collaboration with Dr. Farr and associates, begun to irradiate a second group of patients with a neutron beam of 20 times the original intensity.

Shortly after our initial investigations with boron, lithium was also brought under scrutiny for its capacity to concentrate differentially in brain tumors. Upon first inspection it offered the obvious disadvantages of a capture cross section somewhat less than one-fourth that of B^{10}, and the fact that its toxicity in man was far from completely known. Accordingly, work with this isotope was more cautious. However, we now feel that we are in a position to present our finding and a first approximation of the radiation effects that may arise from its use.

PART I

DETERMINATION OF DIFFERENTIAL CONCENTRATION

Between August, 1951 and April, 1955, 137 patients undergoing craniotomy for tumors were given varying amounts of LiCl intravenously. As the toxicity was little known at the onset the first doses were small, being in the range of 2 grams per adult, given as a 10 per cent solution. After 20 patients receiving this dose failed to manifest any untoward reactions it was increased to approximately 6 grams, given as a 40 per cent solution. With this dose no toxicity was encountered if the patients were anesthetized. However, if the Li was given preceding anesthesia, the patients were often nauseated. Both of these dosages were given in less than one minute. This toxic reaction and local trauma to the vein were greatly reduced by more prolonged administration consisting of 100 to 120 cc. or a 5 per cent solution, or even better approximately 240 cc. of 2.5 per cent solution given over 20 to 60 minutes.

During the operative procedure an endeavor was made to procure samples of scalp, muscle, bone, normal brain and pure neoplasm at varying intervals for determination of the Li content.* Needless to say, the sampling was completely confined to the dictates of therapeutic necessity. Representative microscopic sections were made of the neoplastic and normal brain samples. As it later turned out, many samples thought upon gross inspection to be normal were infiltrated with tumor and showed varying degrees of cellular reaction.† Also many tumor samples were found to be almost completely necrotic. In many cases no normal brain could be obtained. In a few situations it was possible to get enough normal gray matter and normal white matter for separate analysis of each.

For the purpose of studying the differential concentration between neoplasm and normal brain, which we shall hereafter call the localization factor, we selected only those samples on which the histologic aliquots indicated that the chemical analysis had been made on tumor which was for the most part actively growing and

* The method used for the lithium determinations was that of Buell (*J. Biol. Chem.*, 1939, *130*, 357) as modified by one of us (J. Robinson). Trial determinations on tissues containing known amounts of lithium showed that the method had an average error of 6 per cent over the range of concentration encountered in our biopsies.

† We are indebted to Dr. E. P. Richardson and Dr. L. W. Lapham of the Department of Pathology (Neuropathology) for their critical review of these histologic studies.

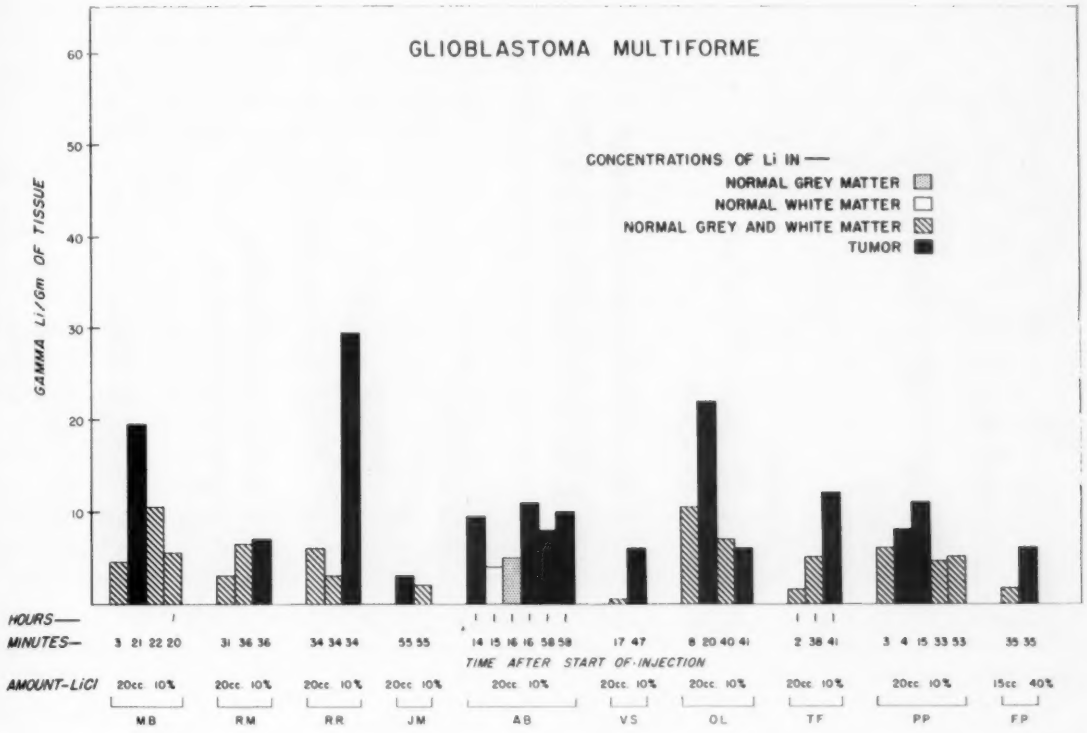
GLIOBLASTOMA MULTIFORME
CONCENTRATIONS OF Li IN —
NORMAL GREY MATTER
NORMAL WHITE MATTER
NORMAL GREY AND WHITE MATTER
TUMOR
GAMMA Li/Gm OF TISSUE
60
50
40
30
20
10
HOURS—
MINUTES— 3 21 22 20 31 36 36 34 34 34 55 55 14 15 16 16 58 58 17 47 8 20 40 41 2 38 41 3 4 15 33 53 35 35
TIME AFTER START OF INJECTION
AMOUNT-LiCl 20cc. 10% 20cc. 10% 20cc. 10% 20cc. 10% 20cc. 10% 20cc. 10% 20cc. 10% 20cc. 10% 20cc. 10% 15cc. 40%
MB RM RR JM AB VS OL TF PP FP

FIG. 1

normal brain which showed no tumor cell invasion. However, because of the paucity of samples totally normal, we were obliged to accept samples with various degrees of cellular reaction. As a result of this selection useful data were obtained from only 73 of the original 137 patients. The results are shown in the bar graphs in Figures 1 to 10. The times noted for each specimen were taken from the start of injection. Consequently, in the cases of prolonged administration, some samples were taken before the total dose was infused.

In Figure 11 are plotted the uptakes of Li by glioblastoma multiforme, normal brain, muscle, bone and scalp from patients receiving circa 6 gm. of LiCl over a 10 minute to 1 hour period. Superimposed upon this is the curve representing the blood level obtained with such dosage. Curves are also drawn for the uptake of normal brain and tumor, but it is obvious that these can be only rough approximations because of the great scatter of the data. On the assumption that the tissue specimens contained approximately 5 per cent serum, a curve representing that percentage of the serum level is included to give evidence that an inconsequential portion of the tissue's Li is in its contained serum. Of significance in this graph is the comparatively long period of several hours over which a large differential concentration exists.

An average localization factor between the times of 10 minutes to 4 hours following injection was obtained for each tumor type and at each dosage in the following way. For every patient a ratio between tumor and normal was taken when the specimens were procured within a few minutes of each other. In the cases where more than one ratio could be taken for any one patient these were averaged so that in the final average each patient was represented by only one datum. The results of this are shown in Table 1.

In addition to the localization factor, the absolute concentration of Li in tumors and normal brain is of great importance in determining the differential radiation energies

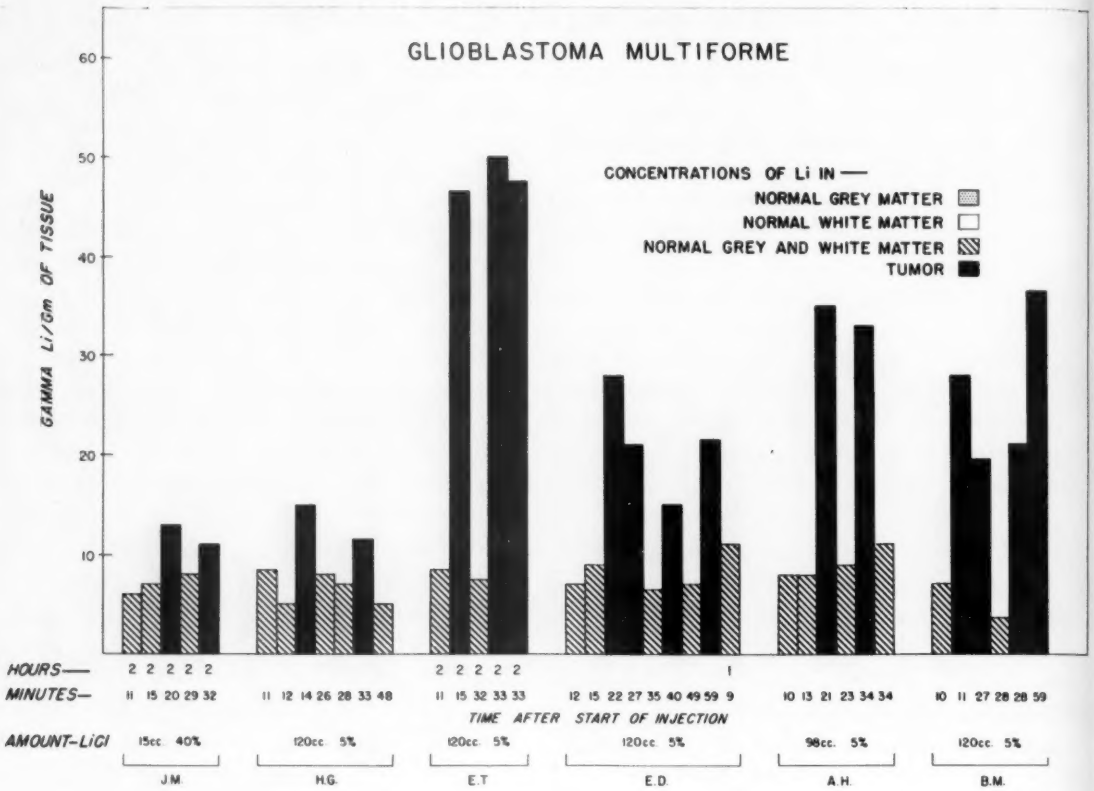
GLIOBLASTOMA MULTIFORME
GAMMA Li/Gm OF TISSUE
60
50
40
30
20
10
CONCENTRATIONS OF Li IN —
NORMAL GREY MATTER
NORMAL WHITE MATTER
NORMAL GREY AND WHITE MATTER
TUMOR
HOURS—
MINUTES—
2 2 2 2 2
11 15 20 29 32
11 12 14 26 28 33 48
2 2 2 2 2
11 15 32 33 33
1
12 15 22 27 35 40 49 59 9
10 13 21 23 34 34
10 11 27 28 28 59
TIME AFTER START OF INJECTION
AMOUNT-LiCl
15cc. 40%
120cc. 5%
120cc. 5%
120cc. 5%
98cc. 5%
120cc. 5%
J.M.
H.G.
E.T
E.D.
A.H.
B.M.

FIG. 2

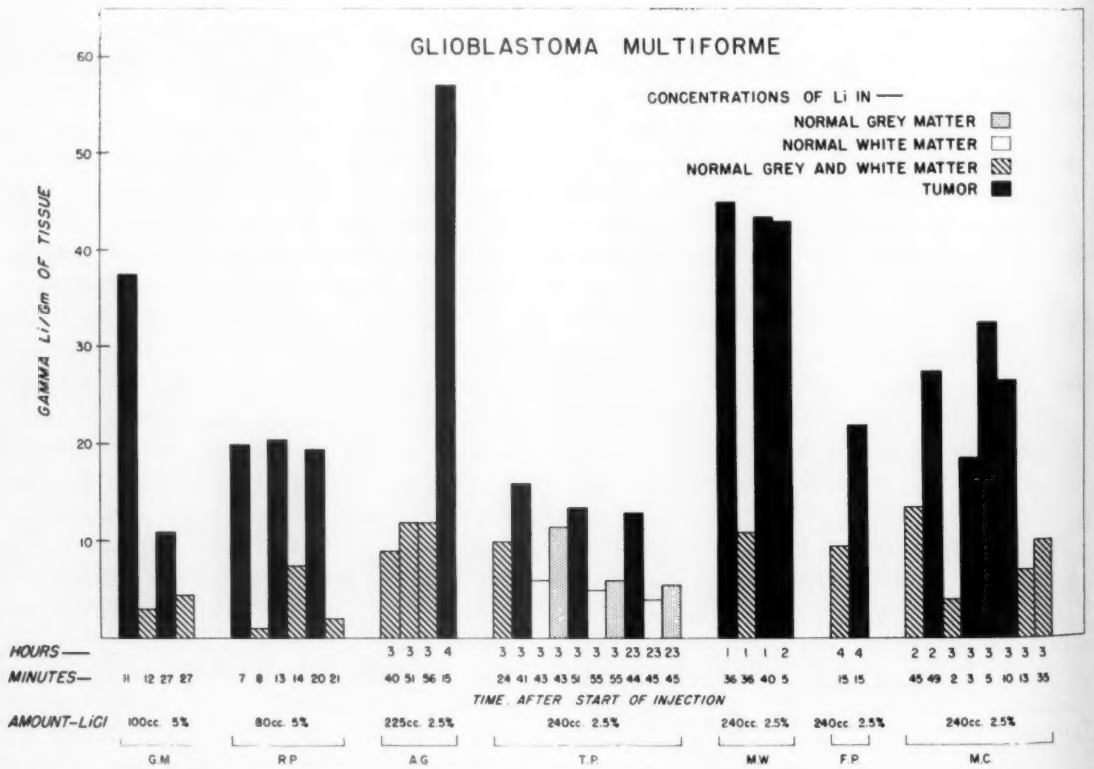
GLIOBLASTOMA MULTIFORME
GAMMA Li/Gm OF TISSUE
60
50
40
30
20
10
CONCENTRATIONS OF Li IN —
NORMAL GREY MATTER
NORMAL WHITE MATTER
NORMAL GREY AND WHITE MATTER
TUMOR
HOURS—
MINUTES—
11 12 27 27
7 8 13 14 20 21
3 3 3 4
40 51 56 15
3 3 3 3 3 3 3 23 23 23
24 41 43 43 51 55 55 44 45 45
1 1 1 2
36 36 40 5
4 4
15 15
2 2 3 3 3 3 3 3
45 49 2 3 5 10 13 35
TIME AFTER START OF INJECTION
AMOUNT-LiCl
100cc. 5%
80cc. 5%
225cc. 2.5%
240cc. 2.5%
240cc. 2.5%
240cc. 2.5%
240cc. 2.5%
G.M
R.P
A.G
T.P.
M.W
F.P.
M.C.

FIG. 3

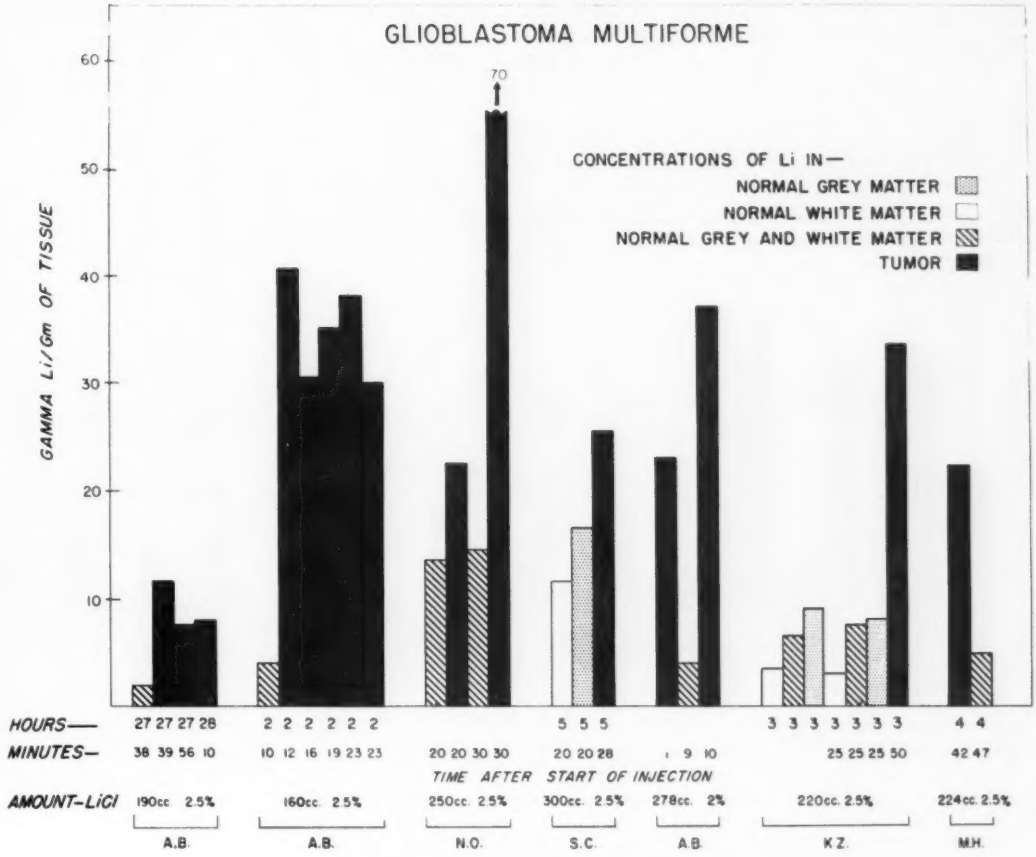
GLIOBLASTOMA MULTIFORME
GAMMA Li/Gm OF TISSUE
60
50
40
30
20
10
70
CONCENTRATIONS OF Li IN—
NORMAL GREY MATTER
NORMAL WHITE MATTER
NORMAL GREY AND WHITE MATTER
TUMOR
HOURS— 27 27 27 28 2 2 2 2 2 2 5 5 5 3 3 3 3 3 3 3 4 4
MINUTES— 38 39 56 10 10 12 16 19 23 23 20 20 30 30 20 20 28 1 9 10 25 25 25 50 42 47
TIME AFTER START OF INJECTION
AMOUNT-LiCl 190cc 2.5% 160cc. 2.5% 250cc. 2.5% 300cc. 2.5% 278cc. 2% 220cc. 2.5% 224cc. 2.5%
A.B. A.B. N.O. S.C. A.B. K.Z. M.H.

FIG. 4

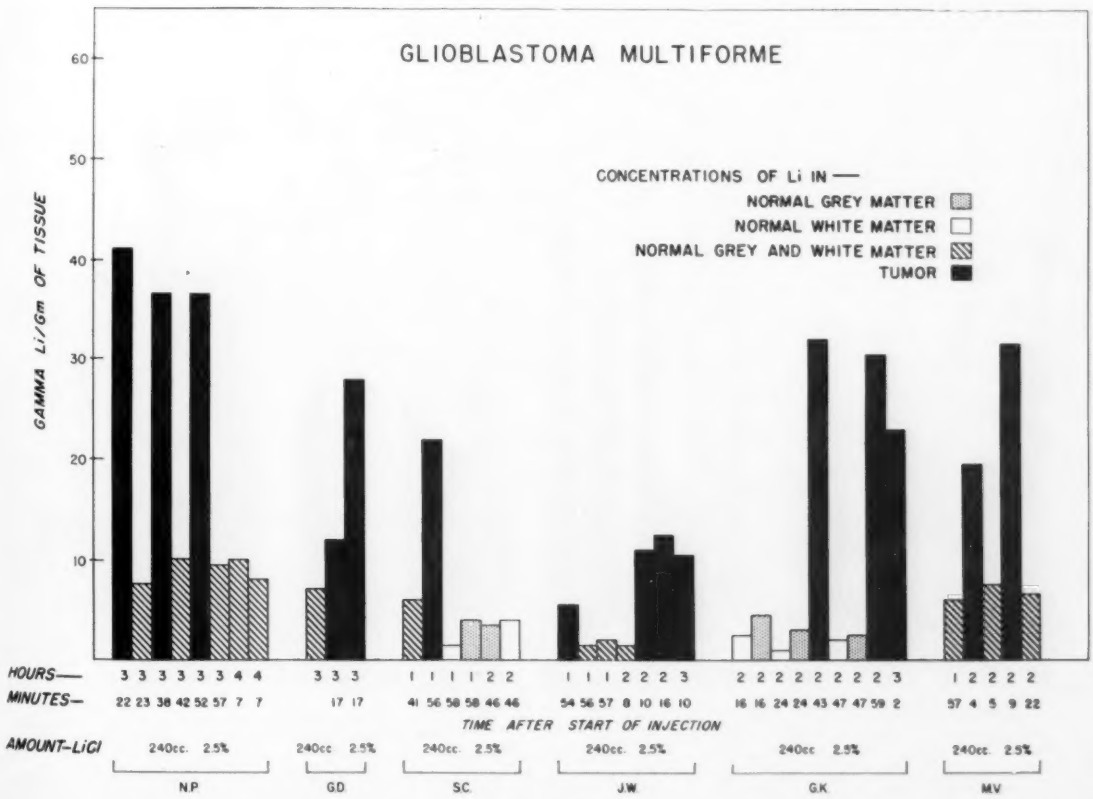
GLIOBLASTOMA MULTIFORME
GAMMA Li/Gm OF TISSUE
60
50
40
30
20
10
CONCENTRATIONS OF Li IN —
NORMAL GREY MATTER
NORMAL WHITE MATTER
NORMAL GREY AND WHITE MATTER
TUMOR
HOURS— 3 3 3 3 3 3 4 4 3 3 3 1 1 1 1 2 2 1 1 1 2 2 2 3 2 2 2 2 2 2 2 2 3 1 2 2 2 2
MINUTES— 22 23 38 42 52 57 7 7 17 17 41 56 58 58 46 46 54 56 57 8 10 16 10 16 16 24 24 43 47 47 59 2 57 4 5 9 22
TIME AFTER START OF INJECTION
AMOUNT-LiCl 240cc. 2.5% 240cc. 2.5% 240cc. 2.5% 240cc. 2.5% 240cc. 2.5% 240cc. 2.5%
N.P. G.D. S.C. J.W. G.K. M.V.

FIG. 5

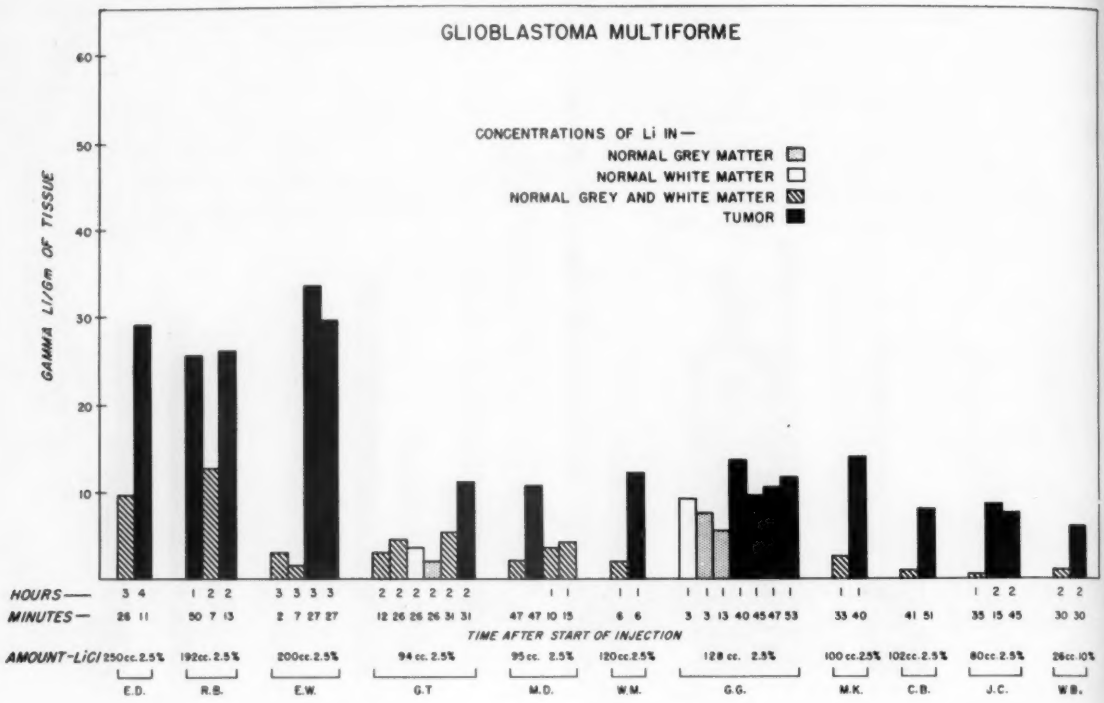
GLIOBLASTOMA MULTIFORME
CONCENTRATIONS OF Li IN—
NORMAL GREY MATTER
NORMAL WHITE MATTER
NORMAL GREY AND WHITE MATTER
TUMOR
GAMMA Li/Gm OF TISSUE
60
50
40
30
20
10
HOURS—
MINUTES—
TIME AFTER START OF INJECTION
AMOUNT-LiCl
E.D.
R.B.
E.W.
G.T
M.D.
W.M.
G.G.
M.K.
C.B.
J.C.
W.B.

FIG. 6

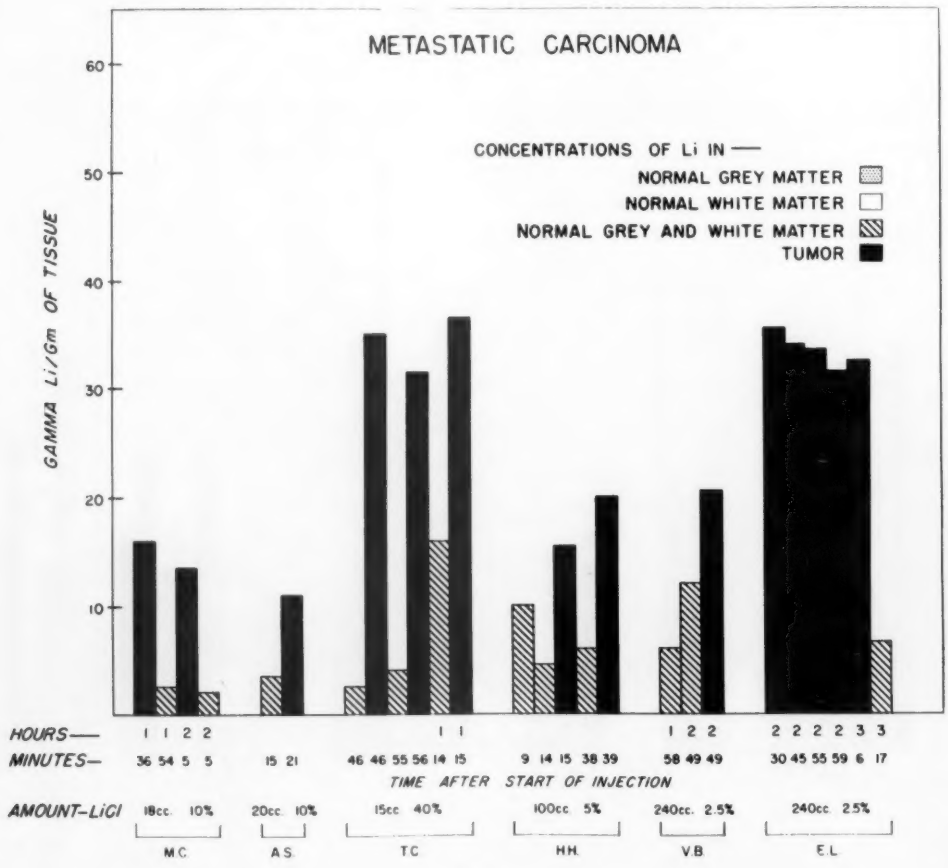
METASTATIC CARCINOMA
CONCENTRATIONS OF Li IN —
NORMAL GREY MATTER
NORMAL WHITE MATTER
NORMAL GREY AND WHITE MATTER
TUMOR
GAMMA Li/Gm OF TISSUE
60
50
40
30
20
10
HOURS—
MINUTES—
TIME AFTER START OF INJECTION
AMOUNT-LiCl
M.C.
A.S.
T.C.
H.H.
V.B
E.L.

FIG. 7

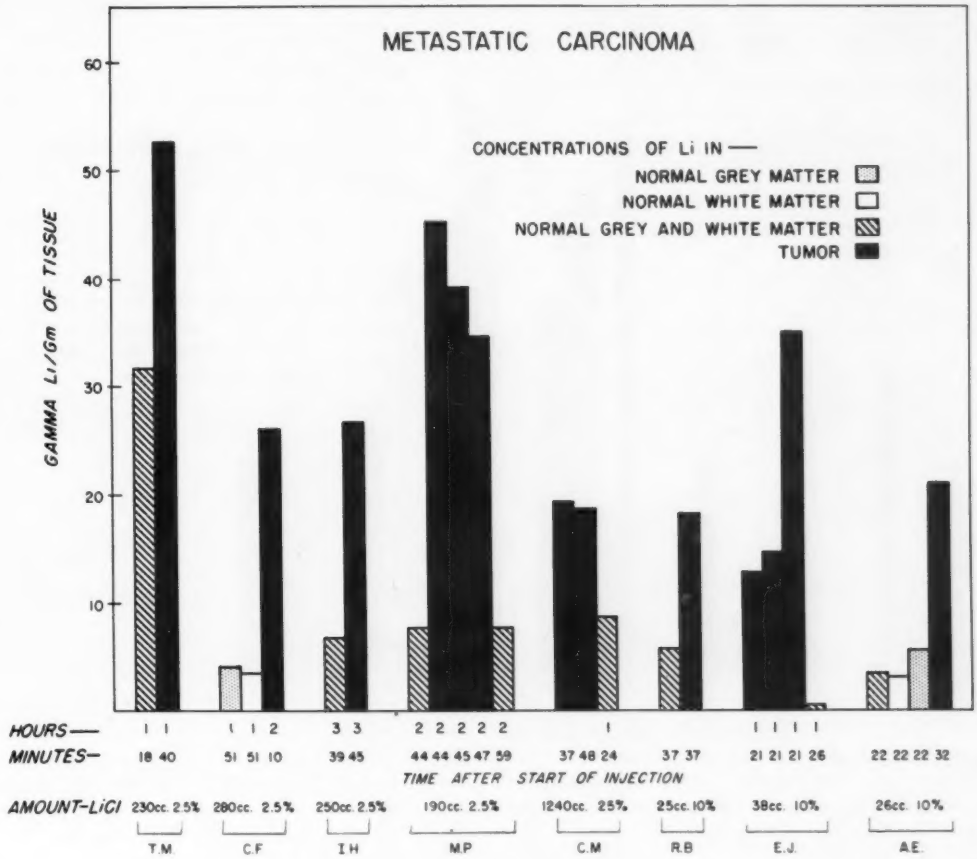
METASTATIC CARCINOMA
CONCENTRATIONS OF Li IN —
NORMAL GREY MATTER
NORMAL WHITE MATTER
NORMAL GREY AND WHITE MATTER
TUMOR
GAMMA Li/Gm OF TISSUE
60
50
40
30
20
10
HOURS — 1 1 | 1 1 2 | 3 3 | 2 2 2 2 2 | 1 | | 1 1 1 1 | |
MINUTES — 18 40 | 51 51 10 | 39 45 | 44 44 45 47 59 | 37 48 24 | 37 37 | 21 21 21 26 | 22 22 22 32
TIME AFTER START OF INJECTION
AMOUNT-LiCl 230cc. 2.5% | 280cc. 2.5% | 250cc. 2.5% | 190cc. 2.5% | 1240cc. 2.5% | 25cc. 10% | 38cc. 10% | 26cc. 10%
T.M | C.F | I.H | M.P | C.M | R.B | E.J. | A.E.

FIG. 8

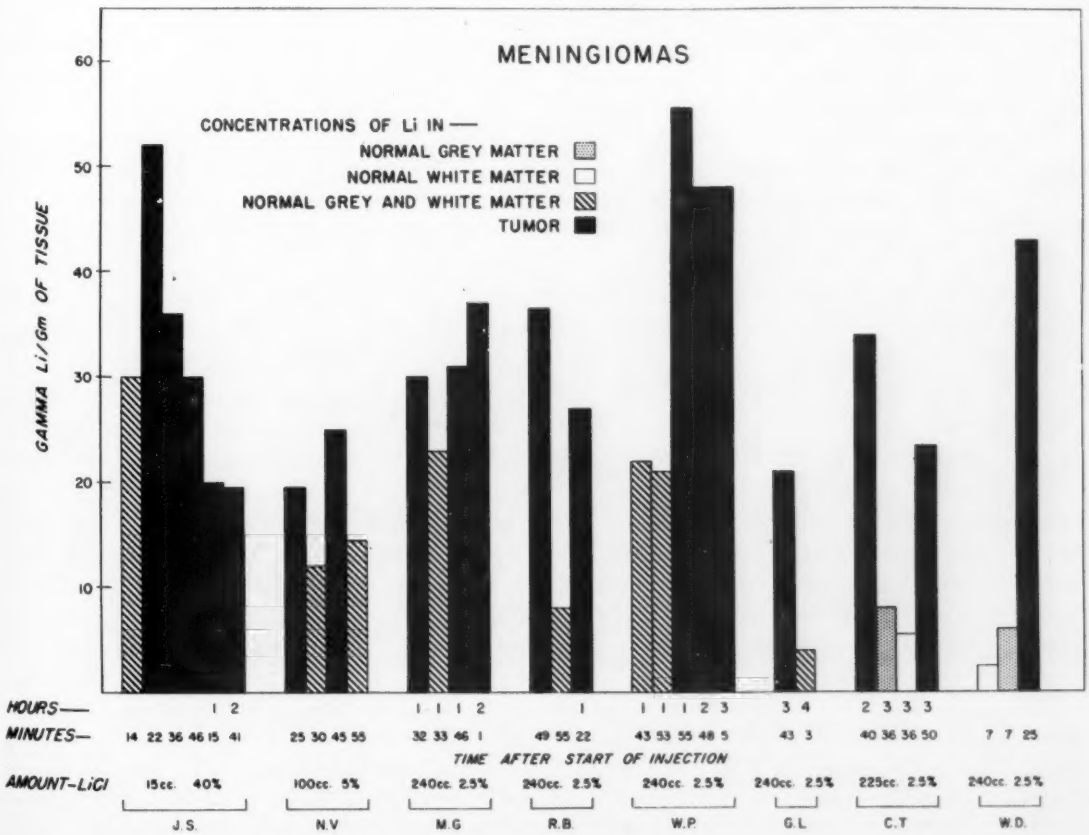
MENINGIOMAS
CONCENTRATIONS OF Li IN —
NORMAL GREY MATTER
NORMAL WHITE MATTER
NORMAL GREY AND WHITE MATTER
TUMOR
GAMMA Li/Gm OF TISSUE
60
50
40
30
20
10
HOURS — 1 2 | 1 1 1 2 | 1 | 1 1 1 2 3 | 3 4 | 2 3 3 3 |
MINUTES — 14 22 36 46 15 41 | 25 30 45 55 | 32 33 46 1 | 49 55 22 | 43 53 55 48 5 | 43 3 | 40 36 36 50 | 7 7 25
TIME AFTER START OF INJECTION
AMOUNT-LiCl 15cc. 40% | 100cc. 5% | 240cc. 2.5% | 240cc. 2.5% | 240cc. 2.5% | 240cc. 2.5% | 225cc. 2.5% | 240cc. 2.5%
J.S. | N.V | M.G | R.B. | W.P | G.L | C.T | W.D.

FIG. 9

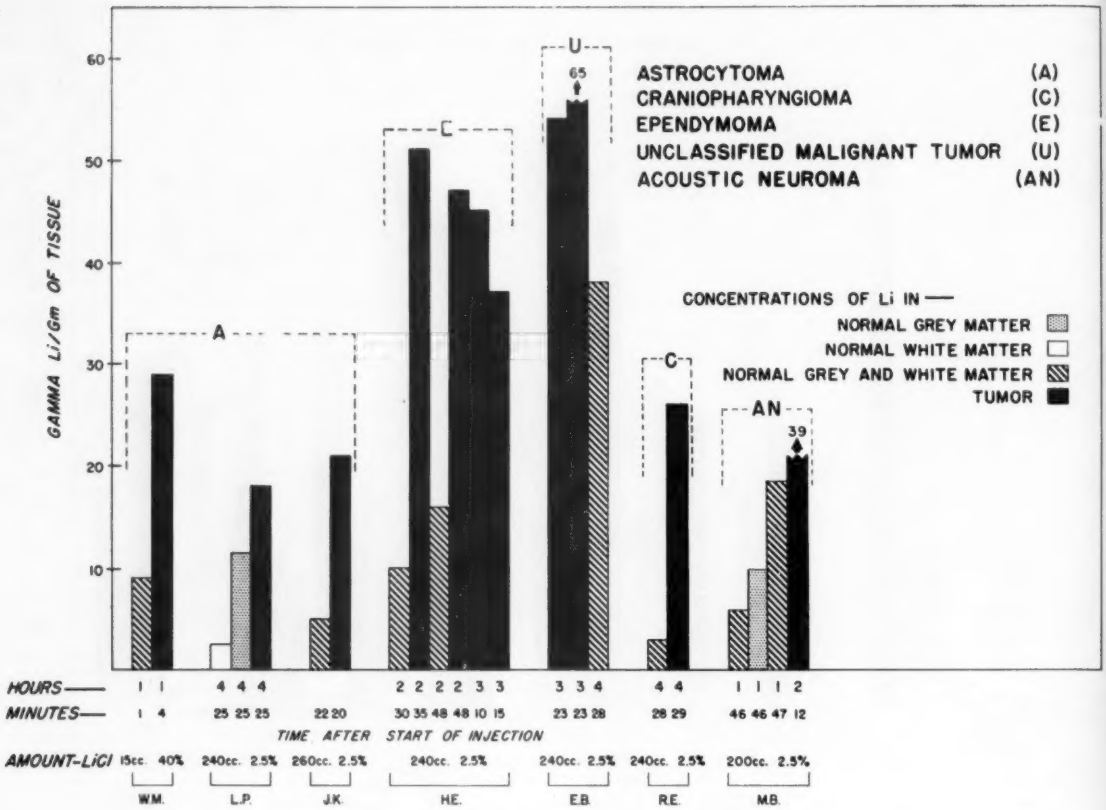

FIG. 10

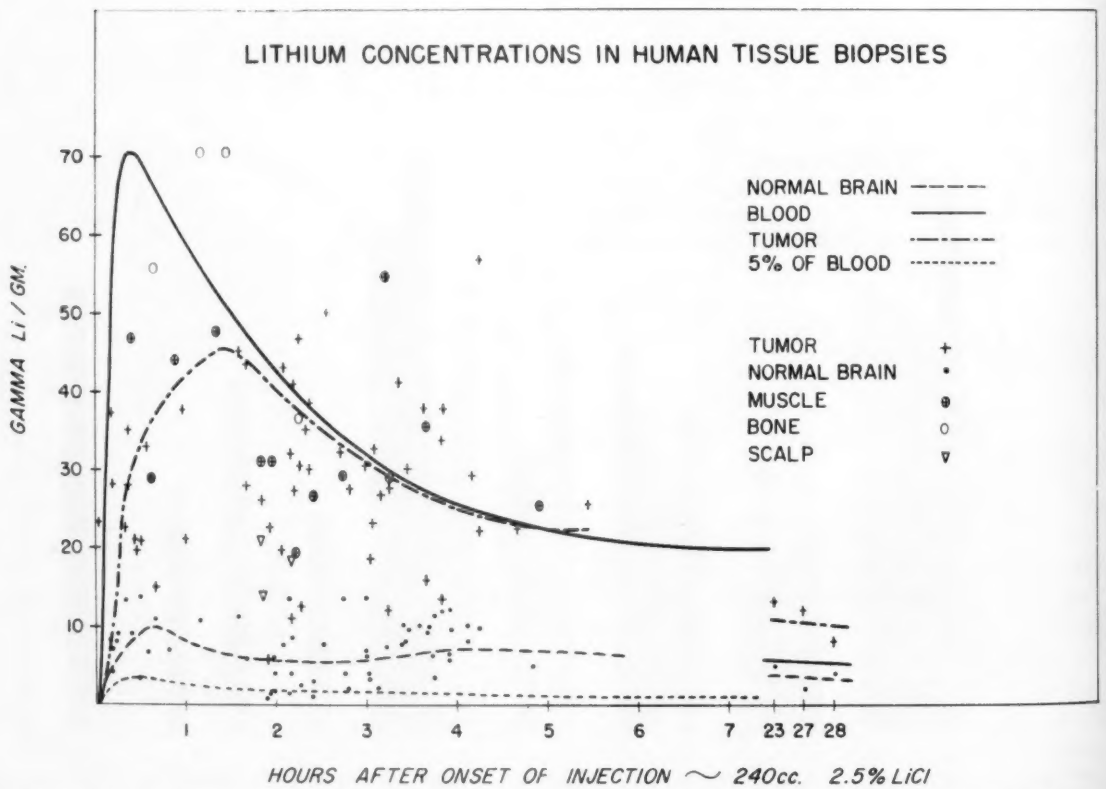

FIG. 11. The lithium content of biopsy specimens of glioblastoma multiforme, normal brain, muscle, bone and scalp taken at varying intervals following infusion of approximately 240 cc. of 2.5 per cent LiCl. The curves for the concentration of glioblastoma multiforme and normal brain are rough approximations.

TABLE I

THE AVERAGE LOCALIZATION FACTORS FOR EACH TYPE OF TUMOR AS CALCULATED FROM THE DATA PRESENTED IN FIGURES 1 THROUGH 10. THE TIME INTERVAL IS 10 MINUTES TO 4 HOURS FOLLOWING THE START OF INFUSION

Tumor	Dose LiCl	No. of Cases	Duration of Infusion	Average Localization Factor
Glioblastoma multiforme	2 gm.	9	approx. 1 min.	1.2
	2 to 3 gm.	8	10 to 30 min.	5.9
	6 gm.	3	approx. 1 min.	2.8
	5 to 6 gm.	26	10 to 60 min.	6.2
Metastatic carcinoma	2 gm.	2	approx. 1 min.	4.0
	6 gm.	1	approx. 1 min.	7.8
	2.5 to 3.8 gm.	3	10 to 20 min.	3.3
	5 to 7 gm.	8	10 to 60 min.	3.9
Meningioma	6 gm.	1	approx. 1 min.	1.7
	5 to 6 gm.	6	10 to 60 min.	3.2
Astrocytoma	6 gm.	1	approx. 1 min.	3.2
	6 gm.	2	20 to 60 min.	3.9
Craniopharyngioma	6 gm.	1	45 gm.	8.7
Ependymoma	6 gm.	1	22 min.	4.0
Acoustic neuroma	5 gm.	1	40 min.	3.5

evolved. This points up the necessity of finding the maximal permissible dose that might be administered to a patient who is not undergoing or about to undergo a craniotomy. To procure these data we selected 5 patients terminal with brain tumors and 1 patient with severe cerebral damage. These patients were given doses of LiCl intravenously ranging from 64 to 250 mg./kg. and were the subject of extensive metabolic studies. The toxic symptoms observed became more severe with increasing dosage. In order of appearance, they consisted of hypersalivation, vomiting, tremor, diarrhea, a flush over the chest and neck, elevation of the pulse and blood pressure, and a temperature elevation of 1 to 2 degrees. They began to appear within a few minutes following the start of infusion and were for the most part mild after 12 to 24 hours. The lowest dose, 64 mg./kg., caused only hypersalivation. The studies indicated that even critically ill patients not facing the rigors of a craniotomy tolerated a dose of 180 to 200 mg./kg. with the support of antiemetics, sedation and intravenous saline. This is approximately twice the dose of 6 gm. which we administered to our craniotomy patients.

DISCUSSION

If the formidable barrier between normal brain and blood breaks down for any reason, more Li will be taken up by the histologically normal-appearing brain and our localization factor will decline. As we have mentioned in a previous communication, the barrier is vulnerable and there is evidence that it gives way as a consequence of cerebral arteriography,[12] and may do so after pneumography and during craniotomy. Hence, in the data we have presented, our so-called normal brain may have taken up an abnormally large amount of lithium.

Some weeks after these procedures, at the

time of therapeutic irradiation, the barrier will have had time to recover from our diagnostic and operative insults, and we can expect a more favorable localization factor. Moreover, at that time the patient will receive a much larger dose of Li and this, as our data appear to suggest, will also tend to increase the localization factor.

From Table I we see that the average localization factor was 6.2 for the 26 glioblastomas receiving circa 6 gm. of LiCl slowly. Furthermore usefully high differentials between tumor and normal brain persisted for 3 to 4 hours as indicated in the curves of Figure 11. This may be contrasted with our data on boron in which the average localization factor was slightly greater than 3 and the useful differentials persisted for only 30 to 45 minutes.

SUMMARY

The literature and rationale for using the physical phenomenon of capture of slow neutrons for localizing radiation damage is presented. One of the most effective capturing nuclides is Li^6. Hence, lithium chloride was administered intravenously in varying concentrations to adults undergoing craniotomy for brain tumors. Biopsies of normal muscle, bone, brain and tumor were examined chemically for Li and one aliquot of the intracranial tissues was examined histologically for confirmation of the nature of the tissue.

Most of the data were obtained using circa 240 cc. of the 2.5 per cent solution, given during 20 to 60 minutes. In 26 cases with glioblastomas receiving this dosage the differential concentrations between neoplasm and normal brain averaged 6.2 during the period of 10 minutes to 4 hours following start of the infusion. In metastatic carcinomas, meningiomas, astrocytomas and an ependymoma the ratios averaged somewhat less.

Studies of the toxicity and metabolism of the Li ion indicate we will be able to give approximately 200 mg./kg. body weight to patients preliminary to radiation therapy.

PART II

ESTIMATION OF RADIATION ENERGIES

With the data of the first part of this presentation as a background we are able to estimate the radiation energies that could be evolved by use of the Li^6 isotope.

For any particular element the energy of ionization per unit time per unit volume equals:

$$F \times N \times \sigma_a \times E \times A$$

where F equals flux, or the number of neutrons crossing a cm.^{2} per second; N equals the number of atoms of the element present per unit volume; σ_a equals the capture cross section or the tendency to capture expressed as apparent area in cm.^{2} presented by a single atom; E equals the energy in million electron volts of radiation emitted after capture of the neturon; A equals the fraction of the energy absorbed in the unit volume.

This equation renders results in mev. (million electron volts) per second. Multiplying by 60 gives mev. per minute. The conversion factor $r = 5.22 \times 10^{13}$ ev. changes results to rep (roentgen equivalent physical per minute. The final form of the equation then is:

$$\text{rep/min.} = \frac{(F \times 60) N \sigma_a (E \times 10^6) A}{5.22 \times 10^{13}}.$$

Utilizing Folch-Pi's data for the concentration of each element in normal cerebral gray matter, normal cerebral white matter and neoplastic brain, Javid, Brownell and Sweet[11] calculated the rep/min. that would be evolved if the incident flux were 1.25×10^9 neutrons/cm.^{2}/sec. and the concentration of B^{10} 15 γ/gm. in the gray matter, 10 γ/gm. in the white matter and 50 γ/gm. in tumor. They elected to use this figure for the neutron flux to compare data with those of Conger and Giles[6] who previously used it while studying the effects of the neutron beam on the buds of the plant Tradescantia at Oak Ridge. Table II is an extension of these calculations to show the rep/min. that would be evolved with Li^6 at

TABLE II

THE REP/MIN. ABSORBED IN NORMAL GRAY MATTER, NORMAL WHITE MATTER, AND GLIOBLASTOMA MULTIFORME WITH A CONCENTRATION OF Li^6 AT 10 γ/CC. IN THE GRAY MATTER, 8 γ/CC. IN THE WHITE MATTER AND 60 γ/CC. IN THE TUMOR, A FLUX OF 1.25×10^9 SLOW NEUTRONS/CM.²/SEC.

Element	Rep/Min. Absorbed in Tissue		
	Normal Gray Matter	Normal White Matter	Tumor
N	1.10	1.08	1.40
Li^6	5.67	4.73	34.27
Other Elements	5.00	5.10	5.00
Totals	11.77	10.91	40.67
Per cent reb/min. due to Li^6	48%	43%	84%

10 γ/cc. in the gray matter, 8 γ/cc. in the white matter and 60 γ/cc. in tumor at the same flux of 1.25×10^9 slow neutrons/cm.²/sec.

With the exception of nitrogen the radiation emitted by the elements occurring naturally in brain and intracranial neoplasm is either beta or gamma. Nitrogen emits a proton with an energy 0.6 mev., and, as previously discussed, Li^6 emits tritium and an alpha particle with a total energy of 4.6 mev. The derivation of a factor for the increased biologic effectiveness of heavy particles over gamma and beta rays is, in these human tissues, for the most part purely speculative. Javid, Brownell and Sweet,[11] basing their decision upon the work of Conger and Giles,[6] arrived at a factor of 70 if the source of the heavy particles were within the nucleus. However, they decided to use a factor of 5 inasmuch as they did not believe that B^{10} would penetrate the nucleus of the cell to a significant extent during the 30 minute period between intravenous injection and completion of exposure to the neutron beam. More recently Farr, *et al.*[9] used a factor of 20 for estimating the radiation dosage received by the patients undergoing neutron capture therapy with boron[10]. Although from data we now have it is apparent that both boron and lithium do penetrate the cell to a significant extent during the first 4 hours following administration, we have, as yet, no clue as to how much is intranuclear. Hence, we have elected to continue to use the more conservative factor of 5 for the RBE (relative biological efficiency) of heavy particles over gamma and beta radiations in order to facilitate our comparison of lithium to boron. Edwards,[8] using radioautographic methods, is seeking quantitative data as to the precise locus of these atoms in order to increase our knowledge of their utility.

Following the lead of Javid, Brownell and Sweet[11] we shall call the factor resulting from rep/min. multiplied by the factor for relative biological efficiency, roentgen equivalent biological (reb). If then we multiply 5 times the rep/min. arising from nitrogen and Li^6 and omit this correction factor for all of the other elements we are in a position to derive the greater radiation energy that would result when Li^6 is added to normal brain and tumor at various concentrations. Table III serves to illustrate

TABLE III

THE EXTENT TO WHICH Li^6 CONTRIBUTES TO THE TOTAL RADIATION ENERGY IN NORMAL GRAY MATTER, NORMAL WHITE MATTER, AND TUMOR AT THE CONCENTRATIONS OF 10 γ/CC., 8 γ/CC. AND 60 γ/CC. RESPECTIVELY IN EACH. THE FLUX FOR THIS CALCULATION WAS 1.25×10^9 n_{th}/CM.²/SEC. AND A FACTOR OF 5 WAS TAKEN FOR THE RELATIVE BIOLOGICAL EFFICIENCY OF HEAVY PARTICLES OVER GAMMA AND BETA REFLECTIONS

Element	Reb/Min. Absorbed in Tissue		
	Normal Gray Matter	Normal White Matter	Tumor
N	5.50	5.40	7.00
Li^6	28.35	23.65	174.35
Other elements	5.00	5.10	5.00
Totals	38.35	34.15	186.35
Per cent reb/min. due to Li^6	72%	69%	94%

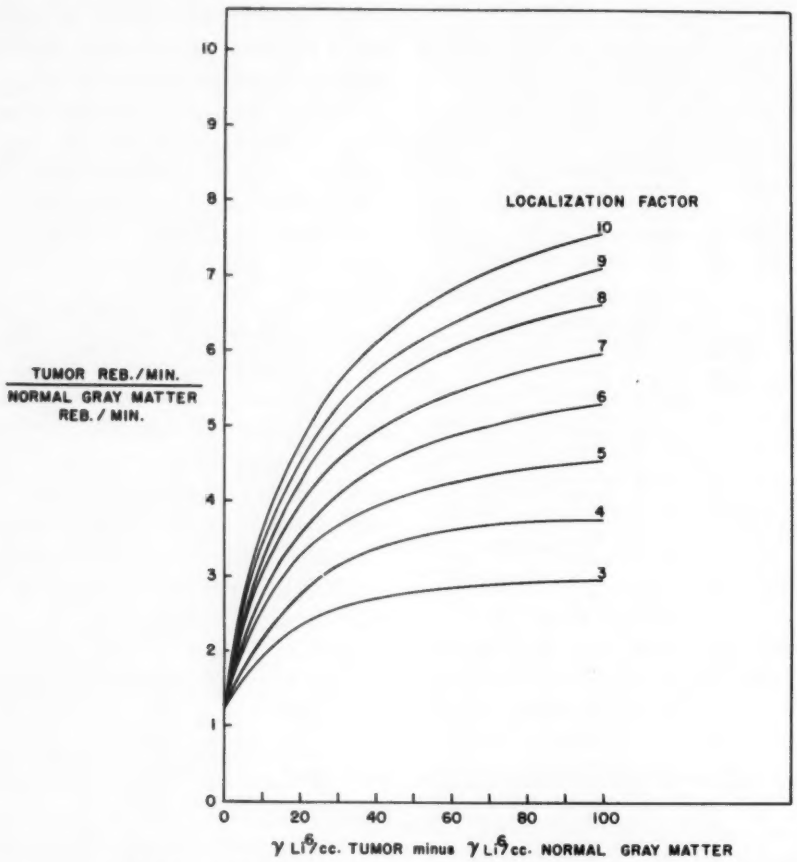

FIG. 12. This illustrates the fashion in which the greater amount of radiation in the glioblastoma multiforme, expressed as the ratio of reb/min. in tumor over reb/min. in normal gray matter, at various localization factors, is influenced by the absolute concentration of Li^6.

the extent to which Li^6 would contribute to the total radiation energy in normal gray matter, normal white matter, and tumor at the concentrations of 10 γ/cc., 8 γ/cc. and 60 γ/cc. respectively in each. The flux for this calculation was 1.25×10^9 n_{th}/cm.^{2}/sec., but the final percentages would be the same for all fluxes. From this table it is apparent that the locus of the Li^6 isotope is the chief determinant of the evolved radiation. However, to a significant degree it falls short of being the sole determinant, and as a consequence of this an important practical consideration emerges. The degree to which radiation is greater in the tumor, expressed as the ratio of reb/min. in tumor over reb/min. in normal gray matter, lags behind the degree to which the Li^6 is more concentrated in the tumor (localization factor). This is graphically portrayed in Figure 12. Here, for example, if the difference in absolute Li^6 concentration between tumor and normal gray matter were 20 γ/cc. and the absolute concentrations so proportioned as to derive a localization factor of 6, this would result in only circa 3.5 times more radiation in the tumor than the normal gray matter. The practical consideration is that only by achieving a high concentration of Li^6 in the tissues will the advantage of the greater concentration in the tumor be reflected by a similarly greater reb/min. evolved in the tumor. The data procured pertaining to the maximum dose that can be safely administered suggests that the ratio of reb/min. in tumor over reb/min. in normal brain will be quite close to the localization factor.

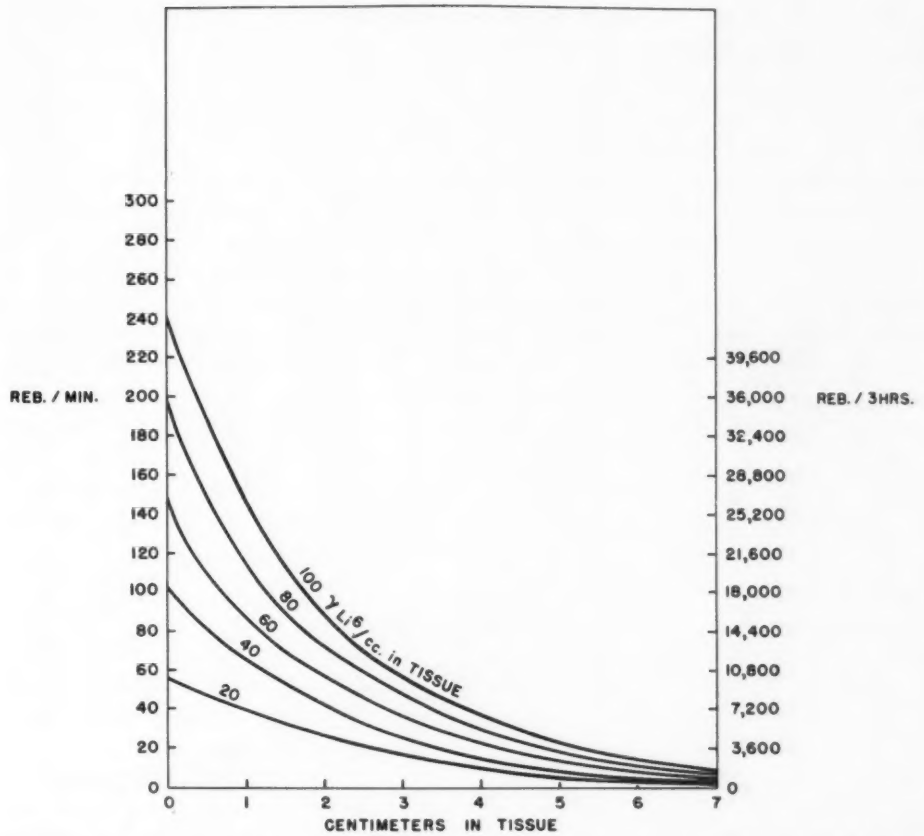

FIG. 13. The family of curves of various Li^6 concentrations in tissue showing the fashion in which the attenuation of the neutron flux influences the reb/min. at progressively increasing depth in the tissue. The flux is taken to be 1×10^9 $n_{th}/cm.^2/sec.$

Another important consideration pertains to the range of the thermal neutrons. This, in air, is of the order of 2,500 cm. However, data pertaining to the range in tissue reveal a marked reduction, a neutron flux being attenuated by a factor of 10 for every 4.5 to 5 cm. of brain tissue penetrated as described by Farr, *et al.*[9] How greatly this influences the reb/min. at progressively increasing depth in brain tissue is depicted by the family of curves representing various Li^6 concentrations in Figure 13. Here, the incident flux is taken to be 1×10^9 $n_{th}/cm.^2/sec.$

How effectively this attenuation dictates the depth to which destructive radiation may be delivered is easily apparent. Moreover, it also defines the depth of tissue in which differential radiation destruction is confined. This is the depth at which the tumor with its high Li^6 content is receiving the same reb/min. as the first part of the normal brain, with low Li^6 content, to be hit by the neutron beam. The curves in Figure 14 were constructed assuming a concentration of 10 γ Li^6/cc. in normal brain. With the tumor concentration anticipated the normal brain at the point of incidence of the flux would be receiving the same reb/min. as the tumor tissue located at a depth of 3 to 4 cm.

The final consideration involves the absolute amount of radiation that can be derived within the confines of the magnitude and attenuation of the flux, absolute Li^6 concentrations, and the magnitude and duration of the localization factor. The ordinate on the right side of Figure 13 shows

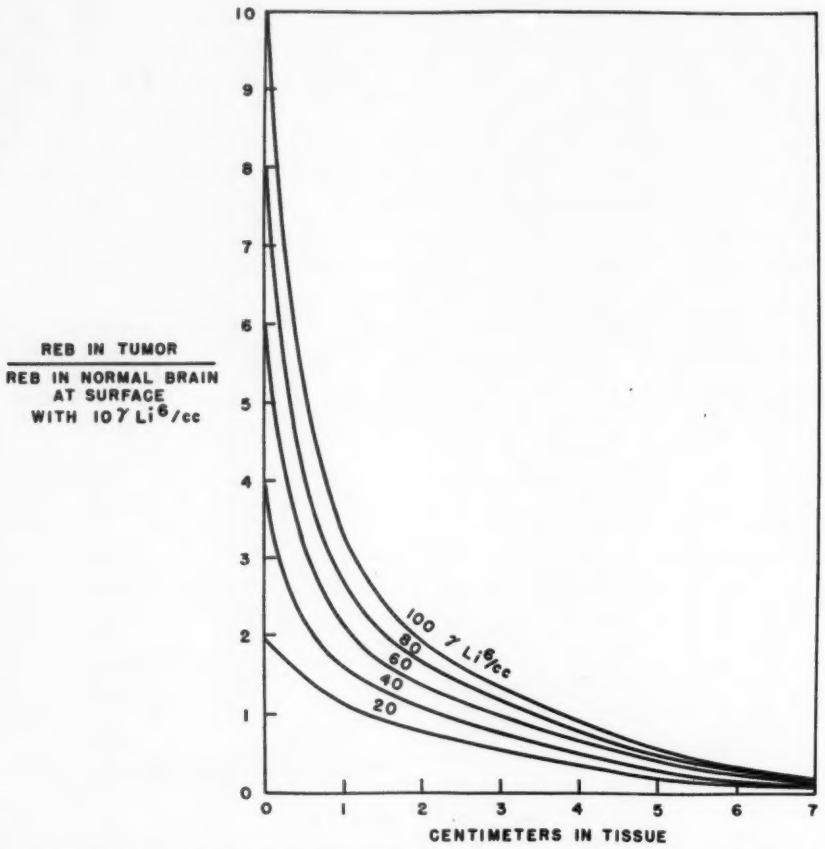

FIG. 14. A family of curves of various Li^6 concentrations in the glioblastoma multiforme showing how the attenuation of the neutron flux limits the depth in tumor in which the reb/min. continue to be greater than the reb/min. in normal gray matter at the surface containing 10 Li^6/cc. The flux is taken to be 1×10^9 n_{th}/cm.^{2}/sec.

the number of reb delivered to various depths in tissue after 3 hours of exposure to a flux of 1×10^9 n_{th}/cm.^{2}/sec. In this time interval the limiting depth to which useful radiation can be delivered may be easily derived. Thus it can be stated that the therapeutic usefulness of the Li^6 isotope is confined to a particular depth of tissue by the parameters of the differential radiation evolved therein and the absolute magnitude of the radiation. This depth is of the order of 3 to 4 cm.

DISCUSSION

The data and calculations presented permit us to advance preliminary estimations of the comparative values of B^{10} and Li^6. At the present time it does not appear that any of the other known neutron capturers will offer equal promise because of their greater toxicity and the fact that they emit long ranged gamma rays rather than the short ranged alpha particles. An exception to this may be uranium^{235} which possesses the comparatively small capture cross section of 370 barns but short ranged fission products which are emitted with energies 30 to 40 times greater than that of Li^6. Zahl and Cooper[27] have alluded to its possible use, and in 1948 Tobias, *et al.*[24] reported animal studies noting the radiation effects of its fission products *in vivo*. Currently we are investigating its possible use in brain tumors.

A rough comparison of the relative efficiencies of B^{10} and Li^6, based upon equal weights, may be made by expressing their relative biological and physical character-

istics, which pertain to neutron capture therapy, as ratios: *i.e.*, comparative capture cross sections $B^{10}/Li^6 = 3{,}900/870 = 4.5$; duration of useful differential concentration $B^{10}/Li^6 = 1/2$ hour/3 hours = .17; energies evolved following neutron capture $B^{10}/Li^6 = 2.4/4.6 = .52$; attainable concentrations in tumor $B^{10}/Li^6 = 125/60^* = 2.1$; average localization factors $B^{10}/Li^6 = 3.3/6 = .55$; and finally, a factor to correct for the greater atomic weight of $B^{10} = .6$. Multiplying these factors yields a ratio $B^{10}/Li^6 = .50$, implying that Li^6 will be 2 times more effective than B^{10}. Most of the advantage of Li^6 stems from its longer duration of differential concentration. If the magnitude of the neutron flux were increased so that an adequate radiation dose could be delivered in a matter of a few minutes, this advantage would be nullified, and B^{10} might prove to be more efficacious because of its greater capture cross section.

There are, though, other major factors about which we know too little to attempt a quantitative comparison. Thus the locus of the atom with respect to the cell is important. We presume that the nearer the disintegrating atom is to the nucleus of the cell the greater the destructive effect. The data of Locksley and Sweet[13] in mice show that boron rapidly enters the intracellular portion of the tissues, the diluting volume being about 100 per cent of the body weight. Our data for man also suggest that Li penetrates the intracellular space, but to an as yet unknown extent. Moreover, we have not yet definitely determined that this penetration includes the intracellular phase of normal and neoplastic brain.

Data concerning the relative radiosensitivity of brain tissue and various types of brain tumors would be of much importance in this study, but, unfortunately, they are incomplete. O'Connell and Brunschwig[16] and Sosman[21] have reported severe damage to normal brain tissue following doses of 6,000 roentgens. Wachowski and Chenault[25] also reported severe damage with doses of 6,000 to 9,000 roentgens, and in 3 of their 6 cases viable tumor cells were still present at autopsy. Pennybacker and Russell[17] have described massive doses of roentgen rays destroying all of large tumors but fatal amounts of normal brain as well. More recently Peirce and Bouchard[18] have reported that a dose of 7,500 to 9,000 roentgens failed to produce any cytologic evidence of damage to normal brain but is the minimum lethal dose for a glioblastoma multiforme. Numerous other workers have reported on the effects in animals.[5,7,15,19] In recent publications Arnold and associates[1,2,3] have demonstrated the late damaging effects of comparatively small doses of radiation on the lower brain centers. At least we know that the damage in neutron capture therapy cannot be unwittingly extended to deep-seated areas of the brain.

* Current doses of B^{10} in borax at the time of neutron capture therapy have been increased by Farr and associates to 50 mg. B^{10}/kg.; 2.5 times as large as the amount yielding 50 γ B^{10}/gm. of tumor in the data of Javid, Brownell and Sweet.[11]

SUMMARY

Calculations based upon Li^6 concentrations of 60 γ/gm. in tumor, 10 γ/gm. in normal gray matter and 9 γ/gm. in normal white matter reveal the locus of the Li^6 isotope will be the chief determinant of the evolved radiation energy when the relative biological efficiency for heavy particles over electrons and gamma rays is taken to be a factor of 5. The rapid attenuation of the neutron flux of 1×10^9 n_{th}/cm./sec. limits the depth in tissue to which useful radiation can be delivered by the factors of differential radiation between the surface and depth of the tissue and absolute magnitude of the radiation. This depth is approximately 3 to 4 cm.

An estimation of the relative efficiencies of B^{10} and Li^6 for the neutron capture therapy of brain tumors at a flux of 1×10^9 n_{th}/cm.^{2}/sec. reveals that Li^6 will be approximately 2 times more effective, largely because of the longer persistence of its localization factor.

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Thirty-ninth Annual Meeting: **Chateau Frontenac, Quebec, Canada, May 30–June 1, 1957.**

EDITORIALS

ROENTGENOLOGY IN RELATION TO NEUROLOGICAL SURGERY

AS IN many other fields of medicine, so in the specialty of neurosurgery the use of the roentgen ray has made great strides and it has become an indispensable aid in both the diagnosis and treatment of lesions coming into this category.

In the very earliest days, about all that could be expected to show on a roentgenogram were gross fractures of the skull as well as fractures and dislocations of the spine. In addition, foreign bodies such as bullets or other metal were likewise demonstrable.

As technique advanced in the first two decades of the twentieth century an increasing number of conditions became recognized. More obscure skull and spinal fractures were disclosed, and evidences associated with increased intracranial pressure became apparent. Obvious bony defects or protuberances, as well as deformations of the skull, such as in oxycephaly, were given definite diagnoses, and meningiomas were indicated more and more frequently by the type of enostosis which they produced, along with a localized form of vascularity. An enlarged or deformed sella turcica, with or without suprasellar calcification often gave clear-cut evidence of the type of lesion with which the neurosurgeon had to deal. In addition to more accurate data in spinal fractures and dislocations, destructive processes in the vertebrae and pedicles were shown as well as abnormal enlargements of the spinal canal with certain tumors.

With the advent of the Potter-Bucky diaphragm, combined with better stereoscopy, which allowed greater detail in the roentgenogram, the study of skull films yielded further characteristics of the meningiomas at various sites, such as thickening of the tuberculum sellae and of the sphenoid wing, to cite two familiar examples. Destruction and widening of the internal auditory meatus in some acoustic neuromas were shown by positioning of the head (Towne), and a shift of the pineal calcification (Naffziger) was a lateralizing aid in detecting many brain tumors. More accurate interpretation of intracranial calcifications as seen in some tumors—meningiomas, oligodendrogliomas, craniopharyngiomas and some angiomas, to mention a few, became increasingly possible.

The next important steps for roentgen diagnosis of neurosurgical lesions came with the advent of ventriculography in 1918 (Dandy) and of myelography with opaque media in 1921 (Sicard and Forestier). By the use of the former the presence and accurate localization of brain tumors were clearly shown in probably over 95 per cent of patients; whereas by previous neurological study and other aids, not more than 65 per cent could be diagnosed or localized.

Myelography has enabled the roentgenologist to determine the site of intraspinal lesions with exactitude not otherwise possible and to distinguish between intramedullary and extramedullary tumors. In like manner extradural tumors and lesions such as protruding intervertebral disks (Mixter and Barr) can be depicted with great accuracy. In the early years of myelography lipiodol was utilized as the contrast medium, but as instances of subsequent cauda equina irritation were reported other media were sought. Thorotrast was found to be too dangerous and air or oxygen was not entirely satisfactory.

Pantopaque has now superseded all other substances in most clinics and has been found to satisfy practically all requirements. It can and should be removed at the end of the fluoroscopic session. In 1927 cerebral angiography (Egas Moniz) was introduced as a further diagnostic method which has been of the utmost importance in neurosurgery. By this means accuracy as to the site of brain tumors has been increased, and in many instances the type of tumor can be predicted by the configuration of the blood vessel picture in the roentgenogram.

Perhaps of still greater importance, angiography has enabled us not only to diagnose but to locate accurately many intracranial vascular conditions, particularly aneurysms, and in recent years an increasing number of these extremely dangerous lesions has either been cured by direct surgical attack, or the danger of rupture has been mitigated by carotid ligation.

* * *

From the time when it was first learned that roentgen rays could in some instances destroy tumor cells, they have been used for this purpose on a variety of cranial and intracranial tumors as well as those involving the vertebral column and the spinal cord. It was discovered in the early days that medulloblastomas were highly susceptible to the rays, and with the increasing knowledge of dosage requirements, some patients with these tumors have been kept free of recurrence for as long as ten years or more. Most of the other gliomatous growths have been resistant to this type of therapy.

Roentgen treatment for pituitary adenomas following surgical removal was used with apparent benefit some thirty-five or forty years ago, and soon thereafter this form of therapy began to be utilized before the institution of surgery. In the early years the results of roentgen therapy on these tumors was not impressive, doubtless because a sufficient dosage was not thought possible and neurosurgeons were unwilling to wait for beneficial results when vision did not improve. During the past six or seven years, however, when a dosage of 4,000 r has been given quite routinely, and probably delivered with the least side effects by the rotational method, it has been found that at least 80 per cent of pituitary adenomas are apparently cured or greatly benefited without resorting to operative removal.

Another type of intracranial tumor, though rare, namely the pinealoma, is perhaps the most permanently cured of all brain tumors by roentgen treatment, some patients having remained free of symptoms up to twenty-five years. Among other miscellaneous types of cerebral and spinal tumors at times influenced favorably for long periods are chordomas, lymphomas, metastatic carcinomas of some kinds, benign giant cell tumors and Schüller-Christian formations.

During the past few years certain technical advances have been made toward more perfect delineation of neurosurgical lesions by roentgenography. These include diskography, introduced by Lindblom in 1950, and methods of serial arteriography. Cineroentgenography may likewise be of value in the future.

In the foregoing, some of the high spots in the relationship of roentgenology to neurosurgery have been touched upon briefly. Even in such a cursory glance, however, it is obvious that revolutionary improvements in the diagnosis and treatment of surgical lesions of the nervous system have come about since Röntgen's discovery. It may well be that these advances are but the threshold of accomplishments which at present are scarcely predictable.

Gilbert Horrax

THE ANNUAL MEETING OF THE AMERICAN RADIUM SOCIETY

THE Thirty-eighth Annual Meeting of the American Radium Society was held in Houston, Texas on April 9, 10 and 11, 1956 at the attractive Shamrock Hilton Hotel. The total attendance of 217 was composed of 93 members, 82 guests and 42 ladies. On Sunday evening, a social hour for members and guests was sponsored by the Houston Committee on Arrangements and was held in the Cork Club of the Hotel. The next morning the meeting was officially called to order by Dr. Grant Beckstrand who delivered the Presidential Address. Emphasis was placed on the need for larger funds for cancer research even though it is recognized that an increase in research grants has been noted over the past thirty years. His main theme was the care of the cancer patient in which he stressed the importance of meticulous ancillary treatment whether the primary management is surgical or radiological. The program continued with a series of four papers related to treatment and anatomy of carcinoma of the cervix. The afternoon scientific session was devoted to the problems of treatment of carcinoma of the breast. It started with two papers, one on end-results of internal mammary chain dissection and the other on considerations in failure to cure breast cancer. A symposium followed on choice and timing of palliative procedures for advanced breast carcinoma moderated by Dr. Joseph H. Farrow of New York City. The methods discussed by the various members of the panel included hormonal therapy, triethylene thiophosphoramide therapy, radiation therapy, proton irradiation of the pituitary gland, ovarian castration, adrenalectomy and hypophysectomy.

The Radium Chemical Company of New York City sponsored a social hour at the Houston Club following which a buffet dinner was served. Dr. Douglas Quick introduced Dr. Lloyd F. Craver who delivered the Janeway Lecture. He spoke on the *Present Status of Treatment of Malignant Lymphomas*. Emphasis was placed on chemotherapy and hormonal therapy used alone or in conjunction with radiation therapy. He expressed his philosophy regarding treatment of Hodgkin's disease by stating that unicentric lesions were managed aggressively, lesions with regional spread treated moderately and lesions of a generalized nature handled by conservative means. However, no hard and fast rule can be followed. In those cases with involvement of only the upper half of the cervical region, surgical removal was advocated.

The second day of scientific sessions included a variety of contributions. In the morning, the subjects included radiation distribution and dose specification in volume implants of radioactive seeds, possible total dosage during childhood by modern radiologic procedures, kinetic "convergent beam" roentgen therapy, radioactive isotopes in the management of carcinoma of the maxillary antrum, radioiron tracer studies as an index of tolerance to radiation, appraisal of statistical reports of the results of therapy and sweat gland carcinoma. Dr. Manuel Riebeling from Guadalajara, Mexico, was guest speaker on "convergent beam" roentgen therapy. During the noon hour, the wives of members and guests were entertained with a luncheon at the beautiful River Oaks Country club.

The afternoon session was opened by Dr. Ivor G. Williams, guest speaker from London, England on the treatment of retinoblastoma by means of radioactive cobalt disks. The second paper was a preliminary report on the evaluation of preoperative roentgen therapy for rectal cancer. Then followed a symposium on cancer of the thyroid gland moderated by Dr. Edgar L. Frazell of New York City. The four members of the panel spoke on the pathologic classification and general behavior of these neoplasms, choice of operation, medical and radiologic therapy (radioisotopes) and further data on the incidence

of cancer following irradiation in infancy for benign conditions.

On Tuesday evening, a social hour for members and guests was held in the Castillian Room following which the group assembled in the Emerald Room for the Annual Banquet. Dr. Grant Beckstrand paid tribute to Dr. Lloyd F. Craver for his outstanding scientific contributions in the lymphoma field and for his excellence as a teacher.

On Wednesday morning, the meetings were held at the M. D. Anderson Hospital in the form of round table discussions. Six groups met simultaneously in separate rooms from 9:00 to 11:00 A.M. and twelve different topics were presented by variously appointed moderators in different fields of cancer therapy. Following these interesting sessions, those in attendance were escorted on tours throughout the entire hospital.

The meeting ended with a luncheon at the Doctors' Club in a nearby building of the campus of the Texas Medical Center. The general enthusiasm of the members of the society coupled with the cordiality of the Houston Committee on Arrangements made this meeting an outstanding success from both the scientific and social aspects.

HARRY HAUSER, M.D.

We regret to announce the death on June 22, 1956 of Dr. Arthur C. Christie, a distinguished member of the American Roentgen Ray Society and editor of this JOURNAL from 1924 to 1930.

AMERICAN ROENTGEN RAY SOCIETY

SECTION ON INSTRUCTION

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Fifty-Seventh Annual Meeting
Hotel Statler, Los Angeles, California
September 25–28, 1956

PRESIDENT-ELECT W. EDWARD CHAMBERLAIN, with the approval of the Executive Council, has requested that the Section on Instruction be continued for the Annual Meeting of 1956. He has arranged his program so that the Instruction Courses will be offered between the hours of 3:00 P.M. and 4:30 P.M. on Tuesday, Wednesday, and Thursday; on Friday the courses will be offered at 1:30 P.M. and will close at 3:00 P.M. Thus a total of 90 minutes has been made available for each course. This makes it possible for instructors to devote some time to discussion and to conference with those attending the courses. No other official activity has been scheduled for these periods of time.

Eleven large rooms have been made available to the Section on Instruction; one course will be offered in each of these rooms each afternoon of the Annual Meeting.

For 1956 the Section on Instruction presents the following program:

(1) Four Single Period Courses (Courses 101, 102, 103, 104) in Nuclear Medicine, with a faculty of 4 instructors and covering 4 periods.

(2) Ten Single Period Courses (Courses 201–211) in Therapeutic Radiology, with a faculty of 11 instructors, and covering 10 periods.

(3) Five Two Period Courses (Courses 301A, 301B, 302A, 302B, 303A, 303B, 304A, 304B, 305A, 305B) and nineteen Single Period Courses (Courses 306–324) in Diagnostic Roentgenology with a faculty of 25 instructors and covering 29 periods.

(4) One Single Period Course (Course 401) dealing with Calibration of X-ray Equipment.

GENERAL INFORMATION

THE FACULTY

1. Bernice B. Borrman, B.A., Radiological Physicist, Section of Biophysics and Biophysical Research, Mayo Clinic, Rochester, Minnesota.
2. John D. Camp, M.D., Head of the Department of Radiology, The Good Samaritan Hospital, Los Angeles; Clinical Professor of Radiology, University of Southern California, Los Angeles, California.
3. Richard H. Chamberlain, M.D., Assistant Professor of Radiology, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania.
4. Vincent P. Collins, M.D., Professor and Chairman of Department of Radiology, Baylor University College of Medicine; Radiologist-in-Chief, Jefferson Davis Hospital, Houston, Texas.
5. George Cooper, Jr., M.D., Professor of Roentgenology, University of Virginia, Charlottesville, Virginia.
6. William E. Costolow, M.D., Clinical Professor of Radiation Therapy of the University of Southern California School of Medicine; Chairman of the Tumor Board of the Los Angeles County General Hospital; President of the Albert Soiland Cancer Foundation, Los Angeles, California.
7. Henry C. Crozier, M.D., Radiologist, Queen of Angels Hospital, Los Angeles, California.
8. John M. Dennis, M.D., Professor and Head, Department of Radiology, University Hospital, University of Maryland, Baltimore, Maryland.
9. H. B. Elkins, M.D., Associate Professor of Radiology, University Hospitals, Iowa City, Iowa.
10. Titus C. Evans, Ph.D., Head, Radiation Re-

search Laboratory, College of Medicine, State University of Iowa, Iowa City, Iowa.

11. Benjamin Felson, M.D., Professor and Director, Department of Radiology, University of Cincinnati College of Medicine; Director, Department of Radiology, Cincinnati General Hospital, Cincinnati, Ohio.

12. Hymer L. Friedell, M.D., Professor of Radiology, Western Reserve University; Director, Department of Radiology, University Hospitals, Cleveland, Ohio.

13. Ross Golden, M.D., Visiting Professor of Radiology, Medical School, University of California at Los Angeles; Professor Emeritus of Radiology, Columbia University; Consultant, Presbyterian Hospital, New York.

14. Hugh F. Hare, M.D., Radiologist, Los Angeles Tumor Institute, Los Angeles, California.

15. John F. Holt, M.D., Associate Professor of Roentgenology, University of Michigan, Ann Arbor, Michigan.

16. Richard G. Lester, M.D., Assistant Professor, Department of Radiology, University of Minnesota Medical School, Minneapolis, Minnesota.

17. Louis Lichtenstein, M.D., Chief Pathologist, Veterans Administration Center, Los Angeles, California.

18. J. Vernon Luck, M.D., Associate Clinical Professor of Orthopedic Surgery, University of Southern California; Medical Director, Los Angeles Orthopedic Hospital, Los Angeles, California.

19. Alexander R. Margulis, M.D., Assistant Professor, Department of Radiology, University of Minnesota Medical School, Minneapolis, Minnesota.

20. Richard H. Marshak, M.D., Associate Radiologist, Mt. Sinai Hospital, New York, New York.

21. Edward B. D. Neuhauser, M.D., Associate in Radiology, Harvard Medical School, Boston, Massachusetts; Radiologist to The Infant's and The Children's Hospitals of Boston, Boston, Massachusetts.

22. Charles M. Nice, Jr., M.D., Ph.D., Assistant Professor of Radiology, University of Minnesota, Minneapolis, Minnesota.

23. Charles A. Owen, M.D., Assistant Professor of Clinical Pathology, Mayo Foundation, University of Minnesota; Consultant, Section of Clinical Pathology, Mayo Clinic, Rochester, Minnesota.

24. David G. Pugh, M.D., Assistant Professor of Radiology, Mayo Foundation, University of Minnesota; Consultant, Section of Diagnostic Roentgenology, Mayo Clinic, Rochester, Minnesota.

25. Douglas Quick, M.B. (Tor.), Attending Surgeon and Director of the Janeway Clinic of The Roosevelt Hospital, New York, New York.

26. Juan A. del Regato, M.D., Assistant Professor of Radiology, University of Colorado Medical School; Director, Penrose Cancer Hospital, Colorado Springs, Colorado.

27. Jeanne Delano Richmond, A.B., Physicist to the Janeway Clinic of the Roosevelt Hospital, New York, New York.

28. Leo G. Rigler, M.D., Professor of Radiology and Chief of Department of Radiology and Physical Therapy, University of Minnesota, Minneapolis, Minnesota.

29. Bernard Roswit, M.D., Chief of the Radiotherapy Service, Veterans Administration Hospital, Bronx, New York; Associate Visiting Radiologist (Therapy), Third Division, Bellevue Hospital; Assistant Clinical Professor of Radiology (Radiation Therapy), New York Univertiy-Bellevue Medical Center.

30. Maurice D. Sachs, M.D., Associate Clinical Professor of Radiology, Western Reserve University School of Medicine, Cleveland, Ohio, and Chief, Radiology Service, Veterans Administration Hospital, Cleveland, Ohio.

31. Robert D. Sloan, M.D., Professor and Director, Department of Radiology, University of Mississippi, Jackson, Mississippi.

32. Justin J. Stein, M.D., Professor of Radiology, University of California at Los Angeles, School of Medicine; Consultant in Oncology, Veterans Administration Hospital, Sawtelle, California.

33. Roderick L. Tondreau, M.D., Assistant Professor of Radiology, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania.

34. Eugene F. Van Epps, M.D., Professor and Head of Department of Radiology, University of Iowa College of Medicine, Iowa City, Iowa.

35. Walter M. Whitehouse, M.D., Assistant Professor of Radiology, University of Michigan Medical School and University Hospital, Ann Arbor, Michigan.

36. John E. Whiteleather, M.D., Director, Department of Radiology, Baptist Memorial Hospital, Memphis, Tennessee.

37. Marvin M. D. Williams, Ph.D., Professor of

Biophysics, Mayo Foundation, University of Minnesota; Consultant, Section of Biophysics and Biophysical Research, Mayo Clinic, Rochester, Minnesota.

38. Barton R. Young, M.D., Director, Department of Radiology, Germantown Hospital; Clinical Professor of Radiology, Temple University, Philadelphia, Pennsylvania.

39. David E. Zion, M.D., Director, Department of Roentgenology, Cedars of Lebanon Hospital, Los Angeles, California.

Conference Periods

Tuesday, Wednesday, Thursday and Friday afternoons

Single Periods.....3:00–4:30 P.M.

(Tuesday, Wednesday and Thursday)

Single Periods.....1:30–3:00 P.M.

(Friday)

Location

The courses will be presented in the rooms of Hotel Statler with the following designations: Mission Room, Cleveland Room, Washington Room, Detroit Room, Boston Room, Buffalo Room, New York Room, Hartford Room, Dallas Room, St. Louis Room, Foy Room. These rooms will be found in the southwest corner of the Ballroom Floor: that corner of the floor bounded by Seventh Street and Francisco Street. Full information will be obtainable at the desk of the Section on Instruction which will be located in the General Registration Area on Sunday and Monday, but in the hallway near the Hartford Room on the following days. Attendants will be at this desk from 2 P.M. to 5 P.M. on Sunday, September 23, and on the remaining days from 8:30 A.M. until 4:30 P.M.

Code

The instruction periods will be designated with the following code:

T, Tuesday	3:00–4:30 P.M.
W, Wednesday	3:00–4:30 P.M.
Th, Thursday	3:00–4:30 P.M.
F, Friday	1:30–3:00 P.M.

How to Register and Obtain Tickets for the Instruction Courses

Admission to the Instruction Courses will be by ticket only.

Following the list of titles and abstracts is a general order sheet. First, second, and third choices for each period should be selected carefully and indicated on the order sheet. It is estimated that the number who can attend each course each day will range between 60 and 120 persons. If the directions given on the order sheet are followed explicitly, errors in completing reservations for the courses will be minimized.

It is possible for one to attend only four periods of instruction, so the condensed schedule given on the last pages of this program should be consulted with care when registering and ordering tickets for the courses.

Reservations for the courses will be made in the order in which the order forms are received. Those who are not members of the American Roentgen Ray Society will be charged the nominal fee of $2.00 per period of instruction, or a maximum fee of $7.00 for four periods. Full-time graduate students in radiology will be admitted without fee, but they will be required to make application for the courses they wish to attend.

Previous to September 15, 1956, the order forms should be sent to the Director, Dr. Harry M. Weber, Mayo Clinic, Rochester, Minnesota. After September 15, 1956, the order forms should be sent directly to Dr. Harry M. Weber, Hotel Statler, Los Angeles, California.

To avoid the confusion always existing on the first days of the meeting, a set of tickets will be mailed to each person whose registration for courses reaches the office of the Director on or before September 15, 1956. The envelope containing the tickets will be labelled in a conspicuous manner. Registrants are urged to be on the lookout for their tickets, and to bring them to the meeting. The success of this plan depends entirely on the cooperation of the registrants.

In case the courses are not filled by the time

of the meeting, tickets will be available at the registration desk of the Section on Instruction on Sunday, September 23, and thereafter during the meeting.

Holders of Tickets

Those who do not have the proper ticket for the course they wish to attend will not be permitted to enter the room. An attendant will be at the door of each conference room to collect the tickets.

DESCRIPTION OF COURSES

COURSE 101

Washington Room **Period: T**

TITUS C. EVANS, Ph.D.
Iowa City, Iowa

The Scope of Nuclear Medicine

This is an introductory survey of the field designed for those beginning or planning to begin work with radioisotopes. Physics and chemistry of radioisotopes will be discussed in simplified terms. Certain advantages and certain limitations of radioisotopes will be mentioned briefly.

General uses of radioisotopes in diagnosis, therapy, research and teaching will be outlined.

Among other topics which may be discussed are the practical ones of organization and administration, such as procurement procedures, instrumentation, radiation protection, storage and disposal.

COURSE 102

Washington Room **Period: W**

CHARLES A. OWEN, M.D.
Rochester, Minnesota

Diagnostic Use of Radioisotopes

A. Metabolic function tests: I^{131} and I^{132} for the measurement of thyroidal uptake, iodide clearance, and radiothyroxine production. TSH/I^{131} test of pituitary function. Radio-electrolytes (Na^{24} and K^{42}) in adrenal disease. Ca^{45} and P^{32} in parathyroid disease. Cu^{64} in Wilson's disease.

B. Hematology: Blood volume determinations with I^{131}-albumin or with Cr^{51}-labeled erythrocytes or plasma proteins. Red cell survival with Cr^{51} and Fe^{59} Iron metabolism and hemachromatosis using Fe^{59}. Co^{60}-vitamin B_{12} in the evaluation of pernicious anemia.

C. Gastroenterology: quantitation of intestinal bleeding with Cr^{51}; liver function test (I^{131}-rose bengal); pancreatic function (I^{131}-albumin).

D. Tumor localization (I^{131}, I^{131}-albumin, P^{32}, etc.)
E. Miscellaneous.

COURSE 103

Washington Room **Period: Th**

HYMER L. FRIEDELL, M.D.
Cleveland, Ohio

Nuclear Medicine: Therapeutic Applications

The therapeutic applications of the following radioactive isotopes will be discussed:

1. Radioactive iodine for diseases of the thyroid including ablation of the normal thyroid for heart disease.
2. Radioactive phosphorus for polycythemia, leukemia, and certain metastatic bone lesions.
3. Radioactive gold for serous surface tumor implants, and for interstitial administration.
4. Radioactive strontium for beta-ray application to eye lesions.
5. Radioactive cobalt in various types of applicators.

The general rationale of radioactive isotopes for therapy will also be discussed.

COURSE 104

Mission Room **Period: F**

RICHARD H. CHAMBERLAIN, M.D.
Philadelphia, Pennsylvania

Nuclear Medicine : Education and Facilities in the Laboratory in Nuclear Medicine

Radiologists are well equipped by their background to be central figures in the clinical uses of the radioactive isotopes, but this position requires much knowledge and experience in addition to what is needed for conventional diagnostic and therapeutic radiologic practice. The "What?", "How?", and "Where?" of the preparation for the practical use of radioactive isotopes will be discussed. The problems connected with procurement and arrangement of laboratory facilities and equipment, the training of technical personnel, and organization of the general program will also receive attention.

COURSE 201

Boston Room **Period: T**

H. B. ELKINS, M.D.
Iowa City, Iowa

Clinical Use of Colloidal Radioactive Gold

Colloidal radioactive gold has been used both as a curative and palliative agent in a variety of conditions. The interstitial use of gold in carcinoma of the cervix and carcinoma of the prostate has been carried

on now for several years and the selection of cases and technique of injection is fairly well standardized.

The use of radioactive gold in the control of pleural and abdominal fluid has been extensive and uniformly fairly successful. Many of the failures are due to improper selection of cases and if only suitable cases are treated, a satisfactory result is obtainable in approximately 70 per cent.

The use of radioactive gold prophylactically in carcinoma of the ovary would seem to merit consideration on theoretical grounds. Clinical experience in this field is limited and of short duration but may be of some value in establishing a pattern of treatment, complications, and possible results.

COURSE 203

St. Louis Room **Period: T**

WILLIAM E. COSTOLOW, M.D.
Los Angeles, California

The Clinical Evaluation of Cobalt-60 Therapy

The instructor will discuss a 1080-curie cobalt apparatus which has been in continuous use at the Los Angeles Tumor Institute since April, 1952. Mention will be made of the palliative value of this apparatus, as well as the apparent temporary arrests of various types of cancer. Skin reactions in various areas, and tumor dosages obtained will be illustrated with lantern slides.

COURSE 204

Foy Room **Period: T**

J. A. DEL REGATO, M.D.
Colorado Springs, Colorado

Radiobiology for Clinicians

The purpose of this course will be to review the effects of radiations on different human tissues, radiophysiologic reactions and untoward effects.

COURSE 205

St. Louis Room **Period: W**

JUSTIN J. STEIN, M.D.
Los Angeles, California

Cancer of the Breast, Its Diagnosis and Treatment

The diagnosis, the pathology, and the natural life history of treated and untreated breast cancer will be presented in detail.

The indications and contraindications for surgical procedures in the treatment of breast cancer will be discussed in detail.

The problems arising with preoperative and postoperative radiation therapy, the indications for ovarian sterilization, and the use of moderate and supervoltage therapy will be discussed in detail.

COURSE 206

Foy Room **Period: W**

J. A. DEL REGATO, M.D.
Colorado Springs, Colorado

The Problem of Cancer of the Bronchus

Cancer of the bronchus having become the most common form of cancer in the United States, is a matter of serious concern from several points of view. This course will be given to a discussion of incidence, etiology, early diagnosis, surgery and radiotherapy of cancer of the bronchus.

COURSE 207

New York Room **Period: Th**

DOUGLAS QUICK, M.B. (TOR.)
New York, New York
JEANNE DELANO RICHMOND A.B.
New York, New York

Is Radium Still Necessary?

The purpose of the course is to point out the conditions and circumstances in or under which radium is of value.

Emphasis will be placed on conditions in which radium provides the major contribution in the control of malignant growth—conditions in which no other source of ionizing radiation, or method of treatment, has so far proved equal to the efficiency of radium.

Also, and in fairness to other sources of beta and gamma radiation, examples of elective uses of these qualities of radiation and/or radium will be given and relative values discussed.

The value of radium will be considered from the standpoint of telecurie therapy, surface or near-contact therapy, intra-cavitary and intra-tumoral application. It may be used for any of these therapy classifications in the form of radium element or radon. Relative values and other practical considerations as between radon and radium element will be discussed.

Finally it must be pointed out that in the best treatment of most major types of cancer no one method or agent or radiation source covers all angles of the given specific problem.

Usually the best results are obtained through a combination of radiations from various sources—that is, roentgen radiation and radium in one or several forms and frequently coupled with operative surgical procedures.

The value of close cooperation between operative surgery and radium, chiefly radium element needle transfixion or radon implantation will be stressed.

COURSE 208

St. Louis Room **Period: Th**

BERNARD ROSWIT, M.D.
Bronx, New York

The Art of Mold Technology in Radiation Treatment of Cancer

The recent trend toward more radical tumor dosage, toward supervoltage radiation, telecurie therapy and the rotational method, poses challenging problems in treatment planning, precision, safety, and control. The art of mold technology, when applied to maximum advantage in radiation therapy, enhances the probability for cure, and minimizes the risk of serious complication.

This course will deal with a variety of mold techniques developed in our Radiation Clinic over the past five years. The aim has been to improve tumor localization, to develop a three-dimensional plan of treatment, and the discussion will deal with such items as fabrication of treatment shells, bolus applications, precisional beam orientation, immobilization of the patient, rotational techniques, protection against radiation, therapy with radioisotopes, and training of residents. Actual demonstrations of these applications will be presented in "how to do it yourself fashion," using a living subject.

Mold technology, utilizing the plastic, graphic and mechanical arts as well as medical and radiological physics, is clinically practicable and relatively inexpensive for any radiotherapy service, private or public, large or small. Printed technical manuals illustrating these newer techniques will be furnished each registrant.

COURSE 209

Washington Room **Period: F**

VINCENT P. COLLINS, M.D.
Houston, Texas

Radiation Therapy of Cancer of the Genitourinary Tract

A rational approach to the therapeutic management of neoplasms of the kidney, bladder, and testis will be offered in this course. The techniques of using radium and roentgen rays both in conventional and supervoltage ranges will be discussed in as much detail as the time allotted will permit.

COURSE 210

Dallas Room **Period: F**

CHARLES M. NICE, JR., M.D.
Minneapolis, Minnesota

Irradiation Therapy in Leukemia and Lymphomas

The material to be presented includes presentation of survival studies on lymphatic leukemia and the various lymphomas, including Hodgkin's disease, lymphosarcoma, undifferentiated lymphoblastoma, and giant follicular tumor. The principles to be stressed will include the rationale for intensive radiation therapy of apparently localized forms of all of the conditions in this group, and the importance of palliative and supportive therapy in the generalized forms of these conditions. Material from experimental work in animals will be cited to the extent that they relate to the practical handling of patients.

COURSE 211

St. Louis Room **Period: F**

HUGH F. HARE, M.D.
Los Angeles, California

The Clinical, Biological, and Physical Application of Two-Million Volt Therapy

The course will present the clinical application of two-million volt therapy as an aid in the treatment of cancer. The advantages of this type of therapy compared with other forms of radiation from a clinical and physical approach will be discussed. Cytologic studies before, during, and after therapy have been performed on cancer of the bronchus, bladder, and cervix during the past two years, in order to determine the biologic effect on the normal and malignant cells. This part of the discussion will be combined with the clinical and physical approach.

COURSE 301A
and
COURSE 301B

Mission Room **Periods: W, Th**

ROSS GOLDEN, M.D.
Los Angeles, California

The Small Intestine

I. *Functional Disorders*
- Anatomy
- Physiology
  - Neuromuscular control
  - Chemical mediators
  - Food stimulus
- Technique of examination
- Major symptoms of disorder or disease of the small intestine
- Overactivity of the parasympathetic
  - Diarrhea of emotional origin
  - Functional intussusception
- Parasympathetic blockers
- Porphyria
- Parasympathomimetic drugs
- Insufficient production of acetylcholine with gas distention
  - In hypoproteinemia
  - In hypokalemia
  - Of unknown etiology

Local disorders of function
Spasm of the efferent loop following partial gastric resection
Hypersensitivity of denervation
II. *Organic Diseases*
Physiologic importance of the small intestine
How much can be resected safely?
Statistical study of 168 cases of organic disease
Incidence of bleeding, diarrhea and pain
Length of lesions
Single or multiple lesions
Site of lesions
Results of roentgen examination
Study of neoplasm in 74 cases
Primary carcinoma
Carcinoids
Lymphosarcoma
Secondary tumors
Benign tumors
Incidence of intussusception and ileus
Sources of error
Simulation of inflammation by infiltrating neoplasms
Simulation of neoplasms by short areas of inflammation
Is exact diagnosis in the histologic sense necessary for clinical purposes?

COURSE 302A
and
COURSE 302B

Cleveland Room **Periods: W and Th**

JOHN M. DENNIS, M.D.
Baltimore, Maryland

Problems in Urinary Tract Diagnosis

Period I.

Techniques employed in the diagnosis of urinary tract lesions will be briefly discussed. While aortography, retroperitoneal air studies, nephrotomography and retrograde urography will be covered, emphasis will be placed upon obtaining maximum information from intravenous urographic studies by employing a few additional simple procedures. Illustrations demonstrating these simple procedures and the information obtained from them will be shown.

Following a discussion of techniques, many diagnostic problems of the urinary tract will be presented. Emphasis will be placed upon the diagnosis of these lesions by ordinary urographic procedures.

Period II.

A continuation of the discussion of diagnostic problems of the urinary tract will be presented.

COURSE 303A
and
COURSE 303B

Detroit Room **Periods: W, Fr**

BARTON R. YOUNG, M.D.
Philadelphia, Pennsylvania

Roentgen Examination of the Sinuses and Mastoids

The course will be given in two sessions of 1½ hours each. Discussion will be limited to the sinuses in the first period and to the mastoids in the second session. Technique of examination will be considered initially and then normal and abnormal development from birth to maturity will be discussed and illustrated.

Roentgenologic findings in infections and tumors and complications of chronic infections in the sinuses and mastoids including mucoperiostitis, osteomyelitis, cholesteatoma, otogenic meningitis and brain abscess will be demonstrated. Several other interesting abnormalities will be included in the presentation.

COURSE 304A
and
COURSE 304B

Boston Room **Periods: W and Th**

BENJAMIN FELSON, M.D.
Cincinnati, Ohio

Some Fundamentals in Chest Roentgen Interpretation

Chest roentgen interpretation should not merely represent an attempt to correlate particular shadows with specific diseases, but should be approached with an understanding of the basic principles of anatomy, physiology, pathology, and radiology involved. Some of these principles will be considered and their practical application illustrated.

Among the subjects to be discussed are:

Period I.

1. A method of fluoroscopy
2. The "silhouette" sign
3. The air bronchogram

Period II.

1. Anatomic variations in the pulmonary fissures
2. Lobar collapse
3. Lobar enlargement
4. The disrupted fissure

COURSE 305A
and
COURSE 305B

Foy Room **Periods: Th and F**

MAURICE D. SACHS, M.D.
Cleveland, Ohio

Visualization of the Biliary Tract: A Practical Application of the Oral, Intravenous and Operative Cholangiography

In recent years there has been renewed interest in roentgenography of the biliary tract, particularly the oral, intravenous, and operative methods.

The physiologic anatomy will be reviewed with specific reference to gallbladder function in the normal and abnormal state. The significance of a distended gallbladder failing to respond to fatty meal will be discussed and illustrated. The influence of gastrointestinal ulcer on gallbladder function, particularly the sphincter of Oddi, will be reviewed. Diagnosis of dysfunction of the sphincter of Oddi, pancreatitis and carcinoma will be discussed in detail.

The practicality of intravenous cholografin in demonstrating the bile ducts particularly following cholecystectomy and sphincterotomy will be included. The normal and dilated common duct diameter before and after surgery, as seen during oral, intravenous, and operative cholangiographic studies will be discussed.

Practical pointers for doing operative cholangiography and two movies, one depicting the technique and the other showing the effect of nerve stimulation on the sphincter of Oddi in dogs, will be shown.

COURSE 306

Mission Room **Period: T**

LOUIS LICHTENSTEIN, M.D.
Los Angeles, California

Neoplastic and Non-neoplastic Lesions of Bone

The informal discussion of this topic will be built entirely around actual case material, using the original roentgenograms of the lesions. Emphasis will be placed on the common errors of interpretation observed in consultation work.

COURSE 307

Cleveland Room **Period: T**

WALTER M. WHITEHOUSE, M.D.
Ann Arbor, Michigan

Clinical Applications of Obstetric Radiology

The most effective utilization of the information obtained from roentgenograms of the pregnant patient is achieved by close collaboration between the radiologist and the obstetrician. The radiologist must have an appreciation of the relative importance of his findings and how they are to be correlated with the clinical observations in mapping out the program for any particular problem. The relative frequency of the more common obstetric problems calling for roentgenologic examination will be presented, and an obstetric roentgenologic procedure will be described which will provide adequate information for most of these problems. The practical value of the results and their correlation with clinical and laboratory information to provide solid background for the clinical plan of action to be followed will be stressed.

Continuous joint follow-up and review of cases and the importance of incorporating joint education in obstetric radiology in both radiologic and obstetric postgraduate programs will be emphasized.

COURSE 308

Detroit Room **Period: T**

HENRY C. CROZIER, M.D.
Los Angeles, California

Examination of the Colon

The roentgenologic examination of the colon is considered to be one of the more difficult tasks in diagnostic roentgenology. It is possible that the general level of performance in this field is not as high as it can be made to be.

Presented in this course will be a comprehensive discussion of improvements made in the examination of the colon in the 50 years just passed, including the manufacture of preparations of barium sulphate, methods of preparing patients for the examination, procedures using high and lower concentrations of barium sulphate in suspension, roentgenography with high and low voltages, single and double contrast techniques. Roentgenograms showing various abnormalities of the colon will be shown to illustrate the textual matter presented.

COURSE 309

Buffalo Room **Period: T**

ROBERT D. SLOAN, M.D.
Jackson, Mississippi

The Mesenteric Small Bowel

The course will consist of the following:

(1) A review of the embryology, anatomy and physiology of the small intestine, with emphasis upon roentgenologically pertinent aspects.
(2) A discussion of various techniques and media utilized in roentgenologic examinations of the small intestine.
(3) A discussion of pathologic processes involving the small intestine and their roentgenologic appearances.

COURSE 310

New York Room **Period: T**

EDWARD B. D. NEUHAUSER, M.D.
Boston, Massachusetts

The Roentgen Diagnosis of Congenital Cardiovascular Abnormalities Amenable to Surgery

Many forms of congenital malformation of the heart and great vessels, long considered of academic interest only, are now surgically correctable. Recent advances in roentgen diagnosis and in surgical techniques are leading to the recognition of abnormalities which have been overlooked in the past, and have led to the more accurate diagnosis of many malformations whose major features have long been known.

The roentgen features of patent ductus arteriosus, coarctation of the aorta, stenosis of the pulmonary artery, tetralogy of Fallot, Corvisart's complex, double aortic arch, vascular rings constricting the trachea and esophagus, and anomalies of the right subclavian artery and of the innominate vein should be familiar to all roentgenologists. The diagnostic criteria of these malformations will be discussed.

COURSE 311

Hartford Room **Period: T**

ALEXANDER R. MARGULIS, M.D.
Minneapolis, Minnesota

Arteriography in Peripheral Vascular Disease

The indications and the value of arteriography will be discussed. The problems of technique and contrast media will be elaborated on.

The normal anatomy will be presented, and the diagnostic features of various peripheral vascular diseases will be emphasized.

COURSE 312

Dallas Room **Period: T**

RODERICK L. TONDREAU, M.D.
Philadelphia, Pennsylvania

The Nasopharynx in Health and Disease

A wide variety of diseases involves the nasopharynx. Yet this portion of the body is frequently overlooked in standard clinical examinations. The radiologist will render immeasurable assistance if he routinely observes the nasopharynx in his study of routine roentgenograms of the skull and sinuses.

The discussion will include technique as well as the roentgen appearance of lesions of the nasopharynx and neighboring structures.

COURSE 313

Buffalo Room **Period: W**

JOHN D. CAMP, M.D.
Los Angeles, California

Roentgenologic Changes Associated with Lesions Affecting the Optic Chiasm

The optic chiasm is affected directly or indirectly by many intracranial lesions. Some of these exhibit calcification or changes in bone that permit their recognition and precise localization. Others may be disclosed by angiography or pneumographic studies. The usual roentgen changes accompanying these lesions will be discussed and evaluated.

COURSE 314

New York Room **Period: W**

DAVID G. PUGH, M.D.
Rochester, Minnesota

The Roengenologic Diagnosis of Arthritis

There are two basic problems in the diagnosis of arthritis. The first is to determine if arthritis is present. The second is to distinguish the various types of arthritis. In this discussion on the roentgenologic diagnosis of arthritis we will first investigate the structures in the joint that are affected and note the ways in which alteration in these structures manifest themselves roentgenologically. We will then consider the manner in which various types of arthritis affect joints. This has to do especially with the number and location of the joints affected, and the extent and rapidity of the destructive process. With these factors in mind it is possible to recognize arthritis and identify the type with considerable accuracy.

COURSE 315

Dallas Room **Period: W**

GEORGE COOPER, JR., M.D.
Charlottesville, Virginia

The Collagen Diseases: A Clinical, Roentgenological, and Pathological Correlation

The roentgenological findings in scleroderma, disseminated lupus erythematosus and polyarteritis are now well established and numerous, but often nonspecific and confusing. Accurate diagnosis usually depends upon close cooperation between internist, radiologist, and dermatologist. It is therefore important that the radiologist have a working understanding of the clinical manifestations and pathology of these diseases.

Dermatomyositis and several other conditions considered to belong in the collagen disease group will also be briefly considered.

COURSE 316

Detroit Room **Period: Th**

JOHN E. WHITELEATHER, M.D.
Memphis, Tennessee

Carotid and Vertebral Angiography

This will be a general discussion of methods, angiographic apparatus and procedures, including methods of testing newer contrast media, with movies of actual animal tests.

Although it is not intended to present a catalogue of angiographic pathology, a number of illustrations of tumors, vascular anomalies and hemorrhagic phenoma will be shown. Emphasis will be given to sclerotic and thrombotic involvement of the carotid artery and its branches.

Sufficient time will be allowed for questions and general discussion.

COURSE 317

Buffalo Room **Period: Th**

RICHARD H. MARSHAK, M.D.
New York, New York

Inflammatory Lesions of the Esophagus

The following classification is presented:

(1) Peptic Esophagitis
  (a) associated with sliding hiatus hernia and regurgitation
  (b) associated with duodenal ulcer, intubation and severe vomiting
(2) Isolated ulcer in gastric-lined esophagus
(3) Marginal esophagogastric ulceration
(4) Status following operative procedures in the region of the esophagogastric junction
(5) Scleroderma esophagitis

The roentgen findings in these conditions will be discussed as well as clinical, endoscopic and operative observations. The mechanisms in the production of hiataus hernia, regurgitation and esophagitis will be considered.

COURSE 318

Hartford Room **Period: Th**

RICHARD G. LESTER, M.D.
Minneapolis, Minnesota

Roentgen Diagnosis of Cardiac Lesions in Infants and Children

Since the advent of corrective surgical procedures for many of the cardiac lesions of childhood, the necessity for accurate diagnosis in these patients has become most important. In this course the place of radiology in the clinical examination of patients with heart disease in the pediatric age range will be outlined. Interpretation in terms of pathologic anatomy and physiology will be stressed. Correlation of the roentgen findings with the other clinical procedures and examinations will be presented, and the team approach to diagnosis of cardiac lesions emphasized. The use of conventional roentgen techniques, their value and limitations will be discussed at length. Special procedures, such as angiocardiography and retrograde aortography will be used for confirmation and further discussion, but this course will be oriented to the methods available to all radiologists.

COURSE 319

Dallas Room **Period: Th**

J. VERNON LUCK, M.D.
Los Angeles, California

Correlation of Radiologic and Pathologic Features of Bone Tumors

There is need for further correlation of the reflections of bone tumors in gross anatomy, microscopically and roentgenographically. The material of this course will consist of numerous bone tumors in which the gross material, together with the microscopic and roentgen features, will be carefully correlated. Differential diagnosis will be emphasized and brief comments given on clinical management. Questions from the floor will be encouraged.

COURSE 320

Cleveland Room **Period: F**

EUGENE F. VAN EPPS, M.D.
Iowa City, Iowa

Roentgen Evaluation of Respiratory Distress in Infants and Children

Respiratory difficulty with or without cyanosis, stridor or coughing is common in infants and children. The causes of such symptoms are protean and encompass many organ systems. Correlation of symptoms and signs with the roentgenographic findings will be given.

COURSE 321

Boston Room **Period: F**

DAVID E. ZION, M.D.
Los Angeles, California

The Roentgenologic Aspects of Functional Disturbances of the Gastrointestinal Tract

Almost half of the patients referred to the gastroenterologist are found to have a functional disturbance of the gastrointestinal tract and not organic disease. Because of this, there has been a renewed interest among radiologists regarding the roentgenologic changes observed in these conditions. The three major functional disturbances of the gastrointestinal tract are aerophagia, pyrosis, and functional enterocolonopathy.

A review of the roentgenologic anatomy, clinical findings, physiology and roentgenologic changes, as well as special techniques used in the study of these conditions, will be analyzed in this course.

COURSE 322

Buffalo Room **Period: F**

RICHARD H. MARSHAK, M.D.
New York, New York

The Small Intestine

This course will consider the following:

(1) Roentgen examination of the small intestine:
  (a) Technique
  (b) Utilization of various barium preparations
(2) Tumors of the small intestine:
  (a) Benign
  (b) Malignant
(3) The malabsorption syndrome:
  Spruce and Whipple's disease present the most characteristic findings in this condition. An analysis of the roentgen findings and data accumulated to show the cause of dilatation, segmentation, etc., will be presented.
(4) Infarction of the small intestine.

COURSE 323

New York Room **Period: F**

LEO G. RIGLER, M.D.
Minneapolis, Minnesota

Pneumonitis

Pneumonitis includes many types of pulmonary inflammation. The changes in the roentgenogram resulting from different infections are exceedingly variable. Furthermore, the relationship of the development of roentgen signs to the inception of the process, the onset of symptoms, and the appearance of physical signs, in terms of time, depends on the nature of the process. The presence or absence of roentgen signs, the various roentgen findings which may be observed, and the time relationships referred to above will be discussed and demonstrated. Differential diagnosis from such other processes as congestion, edema, infarct, tuberculosis, atelectasis, non-infectious lesions, and tumors will be elaborated.

COURSE 324

Hartford Room **Period: F**

JOHN F. HOLT, M.D.
Ann Arbor, Michigan

Normal Anatomical Variants as Seen by Radiologists

Anatomic and physiologic variants constitute a large proportion of the problems with which the diagnostic roentgenologist is confronted in his daily practice. Some of the variations are simple and easily recognized; others are more confusing, hence, more interesting. Representative examples of each will be presented.

COURSE 401

Hartford Room **Period: W**

MARVIN M. D. WILLIAMS, Ph.D.
BERNICE B. BORRMAN, B.A.
Rochester, Minnesota

The Thorough Calibration of an X-Ray Machine

The calibration of an x-ray machine should include more than the determination of the roentgens per minute and the half-value layer at the center of the field. Examples of the importance of other information will be presented. Techniques of obtaining data and some of the common sources of error will be discussed.

SECTION ON INSTRUCTION
ORDER SHEET

It is important to register for the Instruction Courses as early as possible since the number admitted to each course will be limited. *It is also very important that first, second and third choices be listed for each period.* All orders for tickets will be filled according to the postmark on the envelopes.

Non-members of the American Roentgen Ray Society, except full-time graduate students in Radiology, will pay $2.00 for each course-period or a maximum of $7.00 for 4 courses. Non-members' fees must accompany this order sheet and will not be returned unless cancellation is received before September 22, 1956.

Tickets for courses will be mailed to each registrant whose order reaches the office of the Director on or before September 15, 1956. They will be sent to the address below unless registrant directs otherwise.

Please fill out the following (type or print):

..... Check ☐ Member ☐ Guest ☐ Graduate Student in Radiology at:

Last Name First Name or Initials

.....

Street Address

....

City State

Those whose advance registration reaches the office of the Director after September 15, 1956, may obtain their tickets at the Registration Desk of the Section on Instruction on the Ball Room Floor, Hotel Statler, on Sunday, September 23, 1956 and thereafter. At this time tickets may also be obtained for courses not filled.

For convenience in selecting your courses consult the condensed schedule of courses.

BE SURE TO FILL OUT SECOND AND THIRD CHOICES FOR EACH PERIOD

Period	First Choice		Second Choice		Third Course	
	Course No.	Instructor	Course No.	Instructor	Course No.	Instructor
Tuesday						
Wednesday						
Thursday						
Friday						

Previous to September 15, 1956, send this order sheet to:

DR. HARRY M. WEBER, MAYO CLINIC, ROCHESTER, MINNESOTA.

After September 15, 1956, mail to:

DR. HARRY M. WEBER, American Roentgen Ray Society, Hotel Statler, Los Angeles, Calif.

CONDENSED SCHEDULE OF COURSES ON TUESDAY, SEPT. 25, 1956

Code: T **3:00–4:30 P.M.** **Code: T**

Nuclear Medicine, Therapeutic Radiology, Miscellaneous Subjects		Diagnostic Roentgenology	
101—Evans Washington Room	The Scope of Nuclear Medicine	**306—Lichtenstein Mission Room**	Neoplastic and Non-neoplastic Lesions of Bone
		307—Whitehouse Cleveland Room	Clinical Applications of Obstetric Radiology
201—Elkins Boston Room	Clinical Use of Colloidal Radioactive Gold	**308—Crozier Detroit Room**	Examination of the Colon
		309—Sloan Buffalo Room	The Mesenteric Small Bowel
203—Costolow St. Louis Room	The Clinical Evaluation of Cobalt-60 Therapy	**310—Neuhauser New York Room**	Congenital Cardiovascular Abnormalities Amenable to Surgery
204—del Regato Foy Room	Radiobiology for Clinicians	**311—Margulis Hartford Room**	Arteriography in Peripheral Vascular Disease
		312—Tondreau Dallas Room	The Nasopharynx in Health and Disease

CONDENSED SCHEDULE OF COURSES ON WEDNESDAY, SEPT. 26, 1956

Code: W **3:00–4:30 P.M.** **Code: W**

Nuclear Medicine, Therapeutic Radiology, Miscellaneous Subjects		Diagnostic Roentgenology	
102—Owen Washington Room	Diagnostic Use of Radioisotopes	**301A—Golden Mission Room**	The Small Intestine, Part I
		302A—Dennis Cleveland Room	Problems in Urinary Tract Diagnosis, Part I
205—Stein St. Louis Room	Cancer of the Breast, Its Diagnosis and Treatment	**303A—Young Detroit Room**	Roentgen Examination of the Sinuses and Mastoids
		304A—Felson Boston Room	Some Fundamentals in Chest Roentgen Interpretation
206—del Regato Foy Room	The Problem of Cancer of the Bronchus	**313—Camp Buffalo Room**	Roentgenologic Changes Associated with Lesions Affecting the Optic Chiasm
401—Williams-Borrman Hartford Room	Thorough Calibration of an X-ray Machine	**314—Pugh New York Room**	The Roentgenologic Diagnosis of Arthritis
		315—Cooper Dallas Room	The Collagen Diseases

CONDENSED SCHEDULE OF COURSES ON THURSDAY, SEPT. 27, 1956

Code: Th **3:00–4:30 P.M.** **Code: Th**

Nuclear Medicine, Therapeutic Radiology, Miscellaneous Subjects		Diagnostic Roentgenology	
103—Friedell Washington Room	Nuclear Medicine: Therapeutic Applications	**301B—Golden Mission Room**	The Small Intestine, Part II
		302B—Dennis Cleveland Room	Problems in Urinary Tract Diagnosis, Part II
207—Quick-Richmond New York Room	Is Radium Still Necessary?	**304B—Felson Boston Room**	Some Fundamentals in Chest Roentgen Interpretation
		305A—Sachs Foy Room	Cholangiography, Part I
		316—Whiteleather Detroit Room	Carotid and Vertebral Angiography
208—Roswit St. Louis Room	Mold Technology in Radiation Treatment of Cancer	**317—Marshak Buffalo Room**	Inflammatory Lesions of the Esophagus
		318—Lester Hartford Room	Roentgen Diagnosis of Cardiac Lesions in Infants and Children
		319—Luck Dallas Room	Correlation of Radiologic and Pathologic Features of Bone Tumors

CONDENSED SCHEDULE OF COURSES ON FRIDAY, SEPT. 28, 1956

CODE: F **1:30–3:00 P.M.** **Code: F**

Nuclear Medicine, Therapeutic Radiology, Miscellaneous Subjects		Diagnostic Roentgenology	
104—Chamberlain Mission Room	Education and Facilities in the Laboratory in Nuclear Medicine	**303B—Young Detroit Room**	Roentgen Examination of the Sinuses and Mastoids, Part II
209—Collins Washington Room	Radiation Therapy of Cancer of the Genitourinary Tract	**303B—Sachs Foy Room**	Cholangiography, Part II
210—Nice Dallas Room	Irradiation Therapy in Leukemia and Lymphomas	**320—Van Epps Cleveland Room**	Roentgen Evaluation of Respiratory Distress in Infants and Children
211—Hare St. Louis Room	The Clinical, Biological, and Physical Application of Two-Million Volt Therapy	**321—Zion Boston Room**	Roentgenologic Aspects of Functional Disturbances of the Gastrointestinal Tract
		322—Marshak Buffalo Room	The Small Intestine
		323—Rigler New York Room	Pneumonitis
		324—Holt Hartford Room	Normal Variants in Radiology

BOOK REVIEWS

Books sent for review are acknowledged under: Books Received. This must be regarded as a sufficient return for for the courtesy of the sender. Selections will be made for review in the interest of our readers as space permits.

Atlas of Roentgen Anatomy of the Skull. By Lewis E. Etter, B.S., M.D., F.A.C.R., Assistant Professor of Radiology, School of Medicine, University of Pittsburgh. With a section on: The Radiographic Anatomy of the Temporal Bone. By J. Brown Farrior, M.D., F.A.C.S., and a section on: The Roentgen Anatomy of the Skull in the Newborn Infant. By Samuel G. Henderson, M.D., F.A.C.R., and Louise S. Sherman, B.S., M.D. Cloth. Price, $14.75. Pp. 215, with 239 illustrations. Charles C Thomas, Publisher, 301 East Lawrence Avenue, Springfield, Illinois, 1955.

The excellence and value of this atlas was readily appreciated after a short period of use. The opportunity to compare photographs of the dried skull along with roentgenograms as seen in the same projections results in a very clear demonstration of roentgen anatomy. The ingenious method of examining the disarticulated skull has led to the identification and clear explanation of some roentgen shadows not fully identified previously. Roentgenograms and photographs are used to show the lines and shadows that each bone of the skull contributes to the total roentgen image of the skull. Direct labeling of all structures allows quick comparison of film and atlas during routine film reading. Constant use of this atlas should unquestionably improve the evaluation of skull roentgenograms and add to the information to be gained from such examinations. Not only the radiologist, but any of the specialized medical groups who confine their study to structures that involve any portion of the head, should find it a worthwhile tool in their daily work. Certainly students and those training in any of these specialties should find this atlas very valuable.

The temporal bone, which has always been recognized as intricate for precise evaluation by roentgen methods, is described by Dr. J. Brown Farrior in great detail with superb illustrations. Roentgenograms of sections of the temporal bone result in clear visualization of all structures.

There is also a special section devoted to description of the orbits and optic foramina and detailed description of other structures that may be visualized in this area. Erroneous impressions caused by roentgen shadows of bone structure adjacent to the optic canals are corrected.

The final section by Drs. S. G. Henderson and L. S. Sherman is devoted to the roentgen anatomy of the skull of the newborn infant. There is a full evaluation of the variation in the appearance of the skull caused by incomplete ossification with a brief review of the embryologic development.

No attempt has been made to go beyond demonstration of that which can be seen on the plain film examination of the skull.

K. K. Latteier, M.D.

Die Occipito-Cervical-Gegend; Eine diagnostisch-pathogenetische Studie. Von Priv.-Doz. Dr. J. E. W. Brocher, Genf. Cloth. Price, $11.40. Pp. 145, with 91 illustrations. Georg Thieme, Herdweg 63, Stuttgart, Germany, 1955.

This monograph is devoted to a detailed roentgenologic and clinical study of the first and the second cervical vertebrae, their relationship to each other and to the base of the skull. It describes the anatomy and embryology of this area and the routine and special roentgenologic procedures for the study of the region. Of particular interest are studies during flexion, extension and rotation. A long chapter is devoted to the bony anomalies of this region which are of great clinical significance. Dislocations, degenerative changes, inflammatory changes, and finally fractures are discussed in separate chapters.

This is an interesting and well documented study of a clinically important but often neglected area. The text is clear and informative. The illustrations are large and of excellent quality. The monograph is highly recommendable, especially to radiologists, neurologists and orthopedic surgeons.

Richard Schatzki, M.D.

Radiodiagnostic en Ophtalmologie. Par Edward Hartmann and Evelyn Gilles. Cloth. Price, 5.700 fr. Pp. 412, with 497 illustrations.

Masson et C^ie^, Éditeurs, 120 boulevard Saint-Germain, Paris-6^e^, 1955.

This text of 412 pages was written by an ophthalmologist and radiologist. It is not surprising then that the professed aim of a text in clinical radiology is achieved. This orientation is apparent, not only by the generous use of case histories, but also in the space devoted to extra-orbital conditions that produce ocular symptoms and signs.

There are chapters on the orbital walls, the sphenoid fissure and the spheno-maxillary cleft. Discussions follow on fractures, tumors and foreign bodies. Exophthalmus is dealt with in a separate chapter. More than half of the book deals with diseases of extra-orbital structures which produce ocular manifestations. There is discussion of the paranasal sinuses, teeth, lacrimal duct, petrous apex, sella turcica and cranial vault. There are brief notes on brain studies following encephalography, ventriculography, arteriography, etc.

This text apparently replaces a previous atlas of ophthalmic radiology by the senior author which is now out of print. The illustrations are comprehensive, informative and beautifully reproduced. Laminagrams are used and illustrated freely, but stereoscopy is not emphasized. Injection of air, either into Tenon's capsule or into the retrobulbar space, is employed in orbital tumors when conventional roentgenography is non-contributory.

There is little to criticize in this book. It would have been helpful had there been more elucidation of the laminagrams by arrows and /or diagrams, although they are quite comprehensible to those familiar with the technique. The chapters on cranial disease are brief and perhaps are not necessary, but they do serve to round out the subject and would probably be valued for review purposes by non-specialized radiologist and ophthalmologists. This reviewer is glad to see a brief chapter on lesions of the cervical spine which may produce ocular symptoms. In many chapters, differential diagnosis is presented in tabular form. Several pages of references are appended, but chiefly to European literature. The format is in the usual high tradition of the Publisher. The French is clear, concise and easy to read. The book is highly recommended.

Marcy L. Sussman, M.D.

Surgical Forum; Proceedings of the Forum Sessions, Fortieth Clinical Congress of the American College of Surgeons, Atlantic City, N. J., November, 1954. By Committee on Forum on Fundamental Surgical Problems, Harris B. Shumacker, Jr., M.D., F.A.C.S., Indianapolis, Chairman. Cloth. Price, $10.00. Pp. 851, with numerous illustrations. W. B. Saunders Company, 218 W. Washington Square, Philadelphia, Pennsylvania, 1955.

Anyone who has attended a Clinical Congress of the American College of Surgeons will realize that the Forum on Fundamental Surgical Problems has become a most important part of the program. It is in the Forum that the preliminary reports on many important surgical developments are first issued. It is the outlet for much of the surgical investigation going on in this country. The large number of papers submitted each year is evidence of the great studies being made in investigative medicine.

This book is the fifth volume of this type to be published. Composed of 154 articles by 383 contributors, it includes all the papers that were selected for presentation at the 1954 Forum of the American College of Surgeons. The material is divided into ten categories and includes such subjects as anesthesiology, steroids and metabolism, in addition to the usual surgical topics. The introduction to each category is an unusually concise summary of the highlights in that field of investigation. Each category contains an amazing amount of investigative work, much of which is directly related to present clinical problems. Many experimental procedures of potential clinical applicability are presented. This is probably best exemplified in the section on Heart and Great Vessels, which has 135 pages on every conceivable type of experimental procedure. The limited time allowed for the original presentation has kept the papers in compact form.

The volume is unusual in that it can be read as a journal and kept as a ready reference. Fundamental biochemical and physiologic problems concerning the surgical patient are presented in the light of most recent developments. The clinician and medical investigator alike will find this book most useful.

William S. Carpenter, M.D.

Clinical Approach to Jaundice. By Leon Schiff, M.D., Ph.D., Professor of Clinical Medicine, Department of Internal Medicine, University of Cincinnati College of Medicine; Director, Gastric Laboratory, Cincin-

nati General Hospital. Cloth. Price, $3.75. Pp. 113, with 52 illustrations. Charles C Thomas, Publisher, 301 East Lawrence Avenue, Springfield, Illinois, 1954.

This monograph deals practically with the non-surgical differentiation of the various types of jaundice. The clues to be derived from the history and physical examination, the value of the various laboratory tests, and the importance of roentgen examination are discussed briefly. The chapter on needle biopsy of the liver is especially valuable since it represents the author's broad experience with this procedure. Finally, some of the limitations and pitfalls that interfere with the making of a precise diagnosis are enumerated.

For the clinician without ready access to the more extensive works this is a brief, useful presentation of the problem of jaundice.

William S. Reveno, M.D.

Sympathikus Chirurgie. Von Prof. Dr. Paul Sunder-Plassmann, Direktor der Chirurgischen Klinik und Poliklinik der Universität Münster (Westf.). Cloth. Price, DM 54.—. Pp. 162, with 146 illustrations. Georg Thieme, Herdweg 63, Stuttgart, Germany, 1953.

The author, Chief of the Department of Surgery at the University of Münster, has, during the past twenty-five years, spent much effort investigating the finer structures of the peripheral nervous system in minute morphologic detail.

This work, together with the work of the German anatomist, Philip Stöhr, Jr., and the Dutch anatomist, Bolk, is widely reflected in the section entitled "Surgery of the Sympathetic System," which is the most original and best part of the book.

The introduction deals almost exclusively with morphologic data, and as one advances through the book, the question arises whether the title "*Surgery* of the Sympathetic System" is not somewhat misleading.

In the chapter on "Indications," the author insists on blocking with novocain before surgery is attempted. Following the view of Leriche and Fontaine, he believes that the frequently long-lasting beneficial effect of novocain blocking is due to the temporary interruption of impulses from higher centers leading to autoregulatory processes in the periphery, thus giving the periphery a chance to resume a new level of tonus, lasting for the duration of the blocking of the trunk. After describing the technique of blocking different regions of the body, the author deals with blocking as a therapy *per se*. This part is illustrated with several good roentgenograms. He reports success in the postoperative management of large subdural hematoma in which the compressed brain would not spontaneously re-expand following surgical evacuation of the hematoma. Re-expansion and dramatic clinical improvement was observed following blocking of the cervical sympathetic. Brief attention is given to the ganglionic blocking agents versus blocking with novocain or surgical interruption of autonomous pathways.

Another section deals with surgical technique and offers nothing new except for the brief mention of the method of Kux (from the University of Graz) of "transpleural endoscopic electrotomy" of the thoracic trunk.

The section on Success and Failure of Sympathetic Surgery gives operative statistics in relation to indications, timing, and methods of surgery, thus demonstrating the tremendous difficulty of clear-cut statistics in evaluation for this type of surgery.

The section "Applications of Surgery of the Sympathetic System," comprises a review of the diseases and syndromes in which operation is proved to be of frequent benefit.

Paper, print and reproduction of illustrations are excellent. There is no bibliography added to the book, although frequent references are made in footnotes to various European and American authors.

This book can be recommended to readers interested in the detailed morphology of the peripheral autonomous nervous system.

Dieter Wendling, M.D.

Radiographic Atlas of Skeletal Development of the Knee. By S. Idell Pyle, Ph.D., and Normand L. Hoerr, Ph.D., M.D. From the Department of Anatomy, Western Reserve University School of Medicine, Cleveland, Ohio. Cloth. Price, $4.25. Pp. 82, with numerous illustrations. Charles C Thomas, Publisher, 301 East Lawrence Avenue, Springfield, Illinois, 1955.

This atlas fills a great need in the problem of correlating skeletal development with the chronologic age. A similar atlas for the hand has previously been published, and others are expected to follow. Several short chapters are devoted to an explanation of the methods of selection of material for this treatise, selection

of skeletal maturity indicators, and determination of skeletal age of maturity indicators. The chapter on development of the knee illustrates the application of the maturity indicators considered most valuable. The final section of the atlas contains a series of reproductions of roentgenograms of the knee at specific ages, beginning with the neonatal period to the age of eighteen, with a listing of the maturity indicators, the developmental features, and interval indicators. Radiologists will find this an outstanding reference work.

D. S. Kellogg, M.D.

The Joints of the Extremities. By Raymond W. Lewis, M.D., Formerly Director, Department of Roentgenology, The Hospital for Special Surgery, New York City. Cloth. Price, $8.50. Pp. 108, with 102 illustrations. Charles C Thomas, Publisher, 301 East Lawrence Avenue, Springfield, Illinois, 1955.

The importance of careful examination of the soft tissues about the joints of the extremities is stressed, and well illustrated. Many of the reproductions of roentgenograms are accompanied by sketches outlining the soft tissue structures and pathology in graphic detail. Some are retouched to accentuate the contrasting shadows shown in the original roentgenograms. The section on the knee is especially good. The author has succeeded well in his announced purpose of presenting non-routine methods, non-routine ideas, and some of the less common pathology of the joints of the extremities. Radiologists will find this a useful reference.

D. S. Kellogg, M.D.

Primeiros ensaios de radioterpia micro-localizada da hipófise e do hipotálamo. Pelo Prof. Dr. Carlos Santos, Da Faculdade de Medkina de Lisboa. Paper. Pp. 69, with 19 illustrations. Author's address, Av. da Liberdade, (11) Lisboa, Portugal, 1953.

This is the text of a report made by the author to the Society of Medical Sciences of Lisbon in December, 1953, on his method for precise irradiation of the hypophysis, in whole or in part, and of the hypothalamus. The patient's head is immobilized in a specially designed fixture; a preliminary roentgenogram permits the exact localization of the sella turcica within a marked circle. Irradiation through a narrow field is thus possible, using the markings on the circle to mask the areas not to be irradiated. Using this device, the author has irradiated patients for a variety of conditions ranging from sphenoidal sinusitis to diabetes and including some tumors. He claims interesting results with the use of relatively small doses of the order of 10 roentgens. He suggests the possibility of using this approach for intensive irradiation of the pituitary with an aim to radiophysiologic "ablation" of the gland for purposes of palliation in cases of advanced cancer.

This ingenious approach to the irradiation of the pituitary gland is not correspondingly supported by radiophysiologic rationale; but the approach may prove useful to those attempting to irradiate pituitary tumors.

J. A. del Regato, M.D.

Angiographic Localization of Intracranial Masses. By Arthur Ecker, M.D., Ph.D., State University of New York College of Medicine, Syracuse Memorial Hospital, Syracuse, New York; and Paul A. Riemenschneider, M.D., State University of New York College of Medicine, Syracuse Memorial Hospital, Syracuse, New York. Cloth. Price, $13.00. Pp. 433, with 413 illustrations. Charles C Thomas, Publisher, 301 East Lawrence Avenue, Springfield, Illinois, 1955.

To use the authors' own words, "This book is a reference atlas." Well written, it is divided into two parts. The first part, covering about 50 pages, presents briefly the normal and pathologic anatomy of the blood vessels of the brain. Line drawings, well chosen and carefully described, serve to orient the student interested in this aspect of neuroradiology.

The second part of the book completes this approxmiately 400 page volume. In it are recorded in logical sequence the usual cerebral angiographic findings in all types of intracranial lesions, localized in every conceivable portion of the brain. As each of twenty-seven focal sites is introduced and discussed, the authors review first the roentgen findings, employing for each focal site drawings demonstrating the displaced blood vessels in the lateral and sagittal planes. Then, case histories, each relatively complete with clinical data and roentgen reproductions, serve to apply and amplify the introductory remarks.

This is a valuable addition to the literature dealing with cerebral angiography. It serves as an excellent corollary to the authors' well received first book which dealt with normal cerebral angiography.

The beautiful illustrations, each about one-half page in size, serve as wonderful teaching material. In view of the excellence of this book and the wide acceptance it already has received, it might have been of additional interest if the roentgenograms had been printed in their original "positive" form.

Philip J. Hodes, M.D.

Hyperostosis cranii. By Sherwood Moore, M.D., Professor Emeritus of Radiology; Washington University School of Medicine; Former Director of the Edward Mallinckrodt Institute of Radiology, St. Louis, Missouri. Cloth. Price, $10.50. Pp. 226, with 107 illustrations. Charles C Thomas, Publisher, 301 East Lawrence Avenue, Springfield, Illinois, 1955.

The subject of hyperostosis cranii has been a controversial one for a number of years. Dr. Moore has presented a large series of cases, thoroughly examined from a roentgenologic, clinical and pathologic point of view. He has investigated, as far as is possible from records, the clinical features associated with hyperostosis cranii: headache, obesity, particularly of the rhizomelic type, hirsutism of the male type in women, psychoneurotic and mental manifestations, and endocrine disorders, as well as the many other less frequent accompaniments. The theory is advanced that hyperostosis and its syndrome are the manifestation of an endogenous imbalance traceable to aberrance in some unknown phase of the process of reproduction.

There are chapters on the etiology, pathogenesis, treatment, prognosis, and social and economic aspect of hyperostosis cranii and its syndrome, as well as on measurements of normal skulls in intact individuals and in museum specimens. There is also a chapter on paleopathology. An extensive bibliography is included in this volume.

The book is interestingly written throughout and gives evidence of the broad background of information the author must possess. It apparently has been a labor of love to elucidate this "fifth pituitary syndrome."

E. F. Lang, M.D.

The Abnormal Pneumoencephalogram. By Leo M. Davidoff, M.D., Professor and Chairman, Department of Surgery of the Albert Einstein College of Medicine, and Director of Surgery, Bronx Municipal Hospital Center. Chief of Neurosurgery, Mount Sinai Hospital, New York, N. Y.; and Bernard S. Epstein, M.D., Chief, Department of Radiology, The Long Island Jewish Hospital, New Hyde Park, N. Y. Second edition. Cloth. Price, $15.00. Pp. 518, with 291 illustrations. Lea & Febiger, 600 South Washington Square, Philadelphia 6, Pennsylvania, 1955.

This second edition of a very well organized and carefully documented presentation of the usefulness of pneumoencephalography has slightly augmented the first edition.

In the introductory chapters the roentgenographic technique is described, basic principles for interpretation given, and the pathology of the tumors of the intracranial cavity concisely discussed.

Subsequent chapters describe the appearance of tumors by location. For each location the clinical picture of a lesion in that area is described and is usually summarized by a listing of the most pertinent features referable to the area, *i.e.*, the information which the roentgenologist should expect to be supplied on the requisition. The literature referable to lesions of the area is then reviewed in considerable detail with liberal quotations of the descriptions of findings by other authors. This is followed by presentation of the authors' material with statistical reports of types of tumors encountered and the incidence of the various abnormal findings in the roentgenographic studies, both in plain films and pneumoencephalography.

Numerous complete case histories with illustrations are included, and usually two or more roentgenograms of each case are reproduced showing the pertinent abnormalities which justify the localization of the lesion. In many cases the photograph of the pathologic specimen is reproduced for correlation.

Each section, in summary, offers a compendium of the literature and the authors' own extensive experience.

Neoplastic disease is very thoroughly covered. Section 2 covers the non-neoplastic disease with particularly interesting sections on subdural hematoma and atrophic lesions of the brain. The vascular anomalies are discussed only briefly, but it is pointed out that these are usually studied by angiography. However, no clear differentiation is made between the cerebral arteriovenous malformations and the Sturge-Weber syndrome, in which the angiomatous formation is only in the meninges, and the brain itself relatively avascular with

convolutional type calcification in its second and third layers of gray matter.

The book offers an extensive bibliography and is well indexed. It is of unusual value as a reference work for the neurologist, neurosurgeon, and radiologist because of the thoroughness with which the literature and authors' cases are reviewed and summarized, and the clarity with which the roentgenographic findings are presented.

Lois Cowan Collins, M.D.

The Year Book of Radiology (1955–1956 Series). Radiologic Diagnosis edited by John Floyd Holt, M.D., Professor, Department of Radiology, University of Michigan; and Fred Jenner Hodges, M.D., Professor and Chairman, Department of Radiology, University of Michigan; Radiation Therapy edited by Harold W. Jacox, M.D., Professor of Radiology, College of Physicians and Surgeons, Columbia University; Chief, Radiation Therapy Division, Radiologic Service, Presbyterian Hospital, New York City; and Morton M. Kligerman, M.D., Associate Professor of Radiology, College of Physicians and Surgeons, Columbia University; Assistant Radiologist, Presbyterian Hospital, New York City. Cloth. Price, $9.00. Pp. 413, with 344 illustrations. The Year Book Publishers, Inc., 200 East Illinois Street, Chicago, Illinois, 1955.

This book is in reality two volumes with one cover. They are bound together because every roentgenologist should be interested in radiation therapy and every radiation therapist should be interested in diagnostic roentgenology. This is as fundamental a fact as that every radiologist must first be a physician.

The volumes on roentgenologic diagnosis and radiation therapy are each ably compiled and edited by two experienced and erudite radiologists. Compilation or gleaning from the literature might be done by anyone, but wise selection which discards the lesser items from the multitude of publications requires great discrimination. Editorial comments critically appraising the published ideas require judgment based on wide experience and a keen sense of values. To those of us who have been privileged to use the year book through many years, the skill with which it continues to be edited is gratifying.

At the time of year when the young radiologist leaves his training center to begin his independent life's work he is of course aware of the need for a library of books and periodicals to enable him to keep abreast of his specialty and to acquire new knowledge as rapidly as possible. He can make no more wise or economical investment than to get the "Year Book" habit. An examination of "The Year Book of Radiology," a reading of the introduction and a brief glance at the interesting articles and illustrations should be proof enough of its value.

Reviewing this book must be confined to general considerations. The material gleaned from thousands of pages of journals and books from all over the world is so varied and condensed that it could only be catalogued in many columns of space. To select the outstanding articles is almost as difficult, for the literature has already been so condensed, abstracted and critically chosen that few topics are not worthy of mention.

To this reviewer the most interesting part of the book is the editorial comments. In many cases we read the comments, then study the article to see if we agree. While realizing the enormous amount of work the editors have done in assembling the volume, one wishes that the editorial notes were more extensive. They are of great assistance in helping the younger men evaluate the techniques, the case reports or the theories advanced in the most recent literature.

Only a few subjects can be mentioned here. Newer developments in cardiovascular radiography, intensification of screen images, xeroradiography, ultra-short roentgen exposure techniques with use of very high voltage, are among the many scientific advances covered by the abstracts. Case reports of unusual conditions, reviews and analyses of cases concerning each body unit are, as usual, important features of the diagnostic section.

Therapeutic radiology vies with its sister half of the book in reader interest. Even to those not specializing in treatment, the concise reports on radiobiologic action, the experimental and proved uses of radioactive isotopes, the latest developments in supervoltage therapy, and the use of the high energy electron beam are absorbing reading. The comments of Dr. Jacox and Dr. Kligerman, while important, could well be expanded, so that their critical appraisal based on their vast experience could be put to fullest use.

Every radiologist should possess the 1955–1956 Year Book of Radiology.

E. Walter Hall, M.D.

BOOKS RECEIVED

Lungenkrebs und Bronchographie. Von Doz. Dr. H. Anacker, Giessen. Cloth. Price $6.80. Pp. 78, with 45 illustrations. Georg Thieme, Herdweg 63, Stuttgart, Germany, 1955.

Diseases of the Skin. By George Clinton Andrews, M.D., F.A.C.P., Clinical Professor of Dermatology, the College of Physicians and Surgeons, Columbia University; Attending Dermatologist to the Presbyterian Hospital, Columbia-Presbyterian Medical Center, New York. Fourth edition. Cloth. Price, $13.00. Pp. 877, with 777 illustrations. W. B. Saunders Company, West Washington Square, Philadelphia 5, Pennsylvania, 1954.

Die Occipito-Cervical-Gegend; Eine diagnostisch-pathogenetische Studie. Von Priv.-Doz. Dr. J. E. W. Brocher, Genf. Cloth. Price, $11.40. Pp. 145, with 91 illustrations. Georg Thieme, Herdweg 63, Stuttgart, Germany, 1955.

Pediatric X-Ray Diagnosis. By John Caffey, A.B., M.D., Professor of Radiology, College of Physicians and Surgeons, Columbia University; Attending Pediatrician and Roentgenologist, Babies Hospital and Vanderbilt Clinic, New York City; Consulting Pediatrician, Grasslands Hospital, Westchester County, N. Y. Third edition. Cloth. Price, $28.00. Pp. 1059, with 1267 illustrations. Year Book Publishers, Inc., 200 E. Illinois Street Chicago 11, Illinois, 1956.

Fluoroscopy in Diagnostic Roentgenology. By Otto Deustchberger, M.D., Assistant Clinical Professor of Radiology, New York Medical College; Roentgenologist in Charge, Bird S. Coler Memorial Hospital, N. Y.; and Associate Visiting Roentgenologist, Metropolitan Hospital, N. Y. Cloth. Price, $22.00. Pp. 771, with 888 illustrations. W. B. Saunders Company, West Washington Square, Philadelphia 5, Pennsylvania, 1955.

Differentialdiagnostik der Lungenkrankheiten. Von Dr. Lasar Dünner, Chefarzt der Industrial Chest Diseases Clinic in Hull (England); früher ärztl. Direktor des Hospitals Buch-West in Berlin; dirig. Arzt der Abt. für Lungenkrankheiten im Jüdischen Krankenhause in Berlin. Cloth. Price, DM 49.—. Ferdinand Enke, Hafenbergsteige 3, Stuttgart W. Germany, 1954.

Angiographic Localization of Intracranial Masses. By Arthur Ecker, M.D., Ph.D., State University of New York College of Medicine, Syracuse Memorial Hospital, Syracuse, New York; and Paul A. Riemenschneider, M.D., State University of New York College of Medicine, Syracuse Memorial Hospital, Syracuse, New York. Cloth. Price, $13.00. Pp. 433, with 413 illustrations. Charles C Thomas, Publisher, 301 East Lawrence Avenue, Springfield, Illinois, 1955.

Radiodiagnostic en Ophtalmologie. Par Edward Hartmann and Evelyn Gilles. Cloth. Price, 5.700 fr. Pp. 412, with 497 illustrations. Masson et Cie, Éditeurs, 120 boulevard Saint-Germain, Paris-6e, 1955.

Diseases of the Chest. By H. Corwin Hinshaw, M.D., Ph.D., Clinical Professor of Medicine, Stanford University School of Medicine; and L. Henry Garland, M. B.,B.Ch., Clinical Professor of Radiology, Stanford University School of Medicine. Cloth. Price, $15.00. Pp. 727, with 634 illustrations. W. B. Saunders Company, West Washington Square, Philadelphia 5, Pennsylvania, 1956.

Radiation Biology. Volume II. Ultraviolet and Related Radiations. Edited by Alexander Hollaender, Director of Biology Division, Oak Ridge National Laboratory. Cloth. Price, $8.00. Pp. 593, with numerous illustrations. McGraw-Hill Book Company, Inc., 330 West 42nd Street, New York, 1955.

Bronchus und Tuberkulose. Von Dr. A. Huzly, Stuttgart-Gerlingen, und Dr. F. Böhm, Uberruh /Isny. Cloth. Price, $13.55. Pp. 138, with 258 illustrations. Georg Thieme, Herdweg 63, Stuttgart, Germany, 1955.

Die-Röntgen-Untersuchung des Herzens und der Grossen Gefässe. Von Prof. Dr. R. Janker, Prof. Dr. Grosse-Brockhoff, Prof. Dr. R. Haubrich, Dr. H. Lotzkes, Dr. A. Schaede, und Dr. H. Hallerbach. Cloth. Price, DM 34.50. Pp. 222, with 249 illustrations. Verlag W. Girardet, Neumarkstr. 50, Wuppertal-Elberfeld, Germany, 1955.

The Joints of the Extremities. By Raymond W. Lewis, M.D., Formerly Director, Department of Roentgenology, The Hospital for Special Surgery, New York City. Cloth. Price, $8.50. Pp. 108, with 102 illustrations. Charles C Thomas, Publisher, 301 East Lawrence Avenue, Springfield, Illinois, 1955.

Breast Cancer and Its Diagnosis and Treatment. By Edward F. Lewison, B.S., M.D., F.A.C.S., Assistant Professor of Surgery, Johns Hopkins University School of Medicine; Surgeon, Johns Hopkins Hospital; Surgeon, Out-Patient Department, Breast Clinic, Division of Tumor Clinic, Johns Hopkins Hospital. Cloth. Price, $15.00. Pp. 478, with 181 illustrations. Williams & Wilkins Company, Mt. Royal and Guilford Avenues, Baltimore 2, Maryland, 1955.

Roentgen Interpretation of Fractures and Dislocations. By Joseph Levitin, M.D., Chief, Department of Radiology, Mount Zion Hospital, San Francisco, California; and Ben Colloff, M.D., Associate Chief, Department of Orthopedic Surgery, Mount Zion Hospital, San Francisco, California. Cloth. Price, $7.75. Pp. 284, with 258 illustrations. Charles C Thomas, Publisher, 301 East Lawrence Avenue, Springfield, Illinois, 1956.

Pulmonary Carcinoma. Edited by Edgar Mayer, M.D., and Herbert C. Maier, M. D. Cloth. Price, $15.00. Pp. 540, with numerous illustrations. J. B. Lippincott Company, East Washington Square, Philadelphia 5, Pennsylvania, 1956.

A. Liechti—Röntgenphysik. Von Dr. Phil. Walter Minder, Dozent für Physikalische Grundlagen

der Medizinischen Radiologie, Leiter des Radium-Institutes Bern. Cloth. Price, $12.85. Pp. 306, with 264 illustrations. Springer-Verlag, Mölkerbastei 5, Wien 1, Austria, 1955.

Radiographic Atlas of Skeletal Development of the Knee. By S. Idell Pyle, Ph.D., and Normand L. Hoerr, Ph.D., M.D. From the Department of Anatomy, Western Reserve University School of Medicine, Cleveland, Ohio. Cloth. Price, $4.25. Pp. 82, with numerous illustrations. Charles C Thomas, Publisher, 301 East Lawrence Avenue, Springfield, Illinois, 1955.

Myelographie und Ischias. Von Oberarzt Dr. med. K. Reinhardt und Oberarzt Dr. med. K. Panter. Paper. Price, ffrs: 800,—. Pp. 64, with 52 illustrations. West-Ost-Verlag G.M.B.H., Saarbrücken, Saar, 1955.

Cancer of the Lung; Pathology, Diagnosis, and Treatment. By Milton B. Rosenblatt, M.D., Associate Professor of Medicine, New York Medical College, and Visiting Physician and Chief of Chest Clinic, New York City Hospital; and James R. Lisa, M.D., Director, Pathology Service, New York City Department of Hospitals, Director of Laboratories and Pathologist, Doctors Hospital. Cloth. Price, $15.00. Pp. 330, with numerous illustrations. Oxford University Press, 114 Fifth Avenue, New York 11, New York, 1956.

Die Bronchographie. Von Doz. Dr. E. Stutz, Freiburg/Br., und Doz. Dr. H. Vieten, Düsseldorf. Cloth. Price, DM 66.—. Pp. 250, with 181 illustrations. Georg Thieme, Herdweg 63, Stuttgart, Germany, 1955.

Causal Factors in Cancer of the Lung. By Carl V. Weller, M.S., M.D., Chairman of the Department of Pathology and Professor of Pathology in the Medical School, and Pathologist to the University Hospital, University of Michigan, Ann Arbor, Michigan. Cloth. Price, $3.00. Pp. 113, with 20 illustrations. Charles C Thomas, Publisher, 301 East Lawrence Avenue, Springfield, Illinois, 1956.

Radium Therapy; Its Physical Aspects and Extensions with Radioactive Isotopes. By C. W. Wilson, M.Sc., Ph.D., F.Inst.P., Principal Physicist to the Westminster Hospital, London. Second edition. Cloth. Price, $7.50. Pp. 286, with numerous illustrations and tables. The Williams & Wilkins Company, Mt. Royal and Guilford Avenues, Baltimore 2, Maryland, 1956.

Cancer; A Manual for Practitioners. Third edition. Cloth. Price, $2.00. Pp. 321. Published by American Cancer Society (Massachusetts Division), Inc., 462 Boylston Street, Boston 16, Massachusetts, 1956.

Röntgendiagnostik des Hüftgelenks. Von Prof. Dr. Med. R. Glauner, Chefarzt der Röntgen-und Radiumabteilung, Am Marienhospital Stuttgart; und Doz. Dr. Med. Habil. W. Marquardt, Leitender Arzt der Orthopädischen Klinik, "Paulinenhilfe" Stuttgart. Cloth. Price, $13.50. Pp. 168, with 195 illustrations. Georg Thieme, Herdweg 63, Stuttgart, Germany, 1956.

Ankylosing Spondylitis. By J. Forestier, M.D., F.A.C.R. (Hon.), Aix-les-Bains; F. Jacqueline, M.D., Aix-les-Bains; and J. Rotes-Querol, M.D., Barcelona. Translated by A. U. Desjardins, M.S., M.D., F.A.C.P., F.A.C.R. Cloth. Price, $10.75. Pp. 374, with 145 illustrations. Charles C Thomas, Publisher, 301 East Lawrence Avenue, Springfield, Illinois, 1956.

Borderlands of the Normal and Early Pathologic in Skeletal Roentgenology. By Prof. Dr. Alban Köhler. Completely revised with reference to illustrations and to text by Dozent Dr. E. A. Zimmer, Bern/Fribourg. English translation arranged and edited by James T. Case, M.D., D.M.R.E. (Cambridge), Professor Emeritus of Radiology, Northwestern University Medical School, Chicago; Director, Memorial Cancer Foundation, Santa Barbara, California. Tenth edition. Cloth. Price, $24.50. Pp. 723, with 1282 illustrations. Grune & Stratton, Inc., 381 Fourth Avenue, New York 16, New York, 1956.

The Doctor in Personal Injury Cases. By Harold A. Liebenson, Member of Illinois, Chicago and American Bar Associations. Cloth. Price, $4.00. Pp. 123. Year Book Publishers, Inc., 200 E. Illinois Street, Chicago 11, Illinois, 1956.

Annual Review of Medicine. Volume 7. 1956. David A. Rytand, Editor. Cloth. Price, $7.00. Pp. 611, with illustrations and tables. Annual Reviews, Inc., Stanford, California, 1956.

Radiation Dosimetry. Edited by Gerald J. Hine, Veterans Administration Hospital, Boston, Massachusetts; and Gordon L. Brownell, Massachusetts General Hospital, Boston, Massachusetts. Cloth. Price, $22.00. Pp. 932, with 306 illustrations and 114 tables. Academic Press Inc., 125 East 23 Street, New York 10, New York, 1956.

Oral Cancer and Tumors of the Jaws. By George S. Sharp, M.D., F.A.C.S., F.A.C.R. (Ther.), Professor of Pathology, School of Dentistry, Assistant Clinical Professor of Surgery, School of Medicine, University of Southern California, and Director, Pasadena Tumor Institute; Weldon K. Bullock, M.D., M.Sc. (Path.), Associate Clinical Professor of Pathology, School of Medicine, University of Southern California, and Surgical Pathologist, Los Angeles County Hospital; and John W. Hazlet, D.D.S., Lecturer, Oral Tumor Pathology, School of Dentistry, University of Southern California. Cloth. Price, $15.00. Pp. 561, with numerous illustrations. McGraw-Hill Book Company, Inc., 330 West 42nd Street, New York 36, New York, 1956.

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ABSTRACTS OF RADIOLOGICAL LITERATURE

Department Editor: T. Leucutia, M.D., Harper Hospital, Detroit 1, Michigan

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ROENTGEN DIAGNOSIS

Abdomen

Davis, Lawrence A., Huang, Kee-Chang, and Pirkey, Everett L. Water-soluble, nonabsorbable radiopaque mediums in gastrointestinal examination. *J.A.M.A.*, Feb. 4, 1956, *160*, 373–375. (Address: Dr. L. A. Davis, 323 E. Chestnut St., Louisville, Ky.)

The authors point out that barium is not an ideal contrast medium. For the past eighteen months they have been experimenting with sodium acetrizoate (urokon sodium) and diatrizoate sodium (hypaque) in examinations of the gastrointestinal tract. These materials are true solutions, which are relatively nonabsorbable in animals and man. They are miscible with blood, which is valuable in bleeding gastrointestinal lesions and they are of a lower viscosity than barium suspensions which may be of great importance in demonstrating small fistulous connections. Both substances are nontoxic and nonirritant and are absorbed in minimal amount from the gastrointestinal tract. A cathartic effect can be expected after the administration of sodium acetrizoate in large doses.

The main disadvantages to their routine use are their high cost and also their bitterness, which makes them objectionable for oral use.—*Arthur E. Childe, M.D.*

Mendl, Karl, Jenkins, Ritchie T., and Russell Hughes, J. Congenital and acquired syphilis of the stomach; with special reference to the gastric deformity in the various stages, and a report of two cases. *Brit. J. Radiol.*, Jan., 1956, *29*, 48–55. (Address: K. Mendl, Morriston Hospital, Swansea, Wales.)

Since gastric syphilis can be cured by specific medical treatment, the diagnosis of many reported cases has not been substantiated histologically. The authors were able to find only two cases reported in the literature which were proven syphilis. In one, Spirochaeta pallida was found in the sections, and in the other, animal inoculations were made. Reports of only ten cases of congenital syphilis of the stomach were found.

The authors report two cases of syphilis of the stomach. One was in a ten year old girl with a five months history of lassitude, abdominal pain immediately after food, frequent vomiting, and loss of weight. Examination of the stomach with a barium meal showed it to have the appearance of linitis plastica. Aside from the cardiac portion, the stomach appeared greatly shrunken in length and very narrowed, with tapering toward the pylorus. The blood Wassermann test was strongly positive, as it was also in the patient's mother and younger brother. A laparotomy was performed, and a biopsy of the whole thickness of the wall was taken. Histologic examination showed findings consistent with the type of inflammatory changes due to syphilis. On antisyphilitic treatment the remission of symptoms was rapid. The pain and vomiting ceased and she gained weight.

The second case reported by the authors was a 60 year old male with a complaint of central abdominal pain and vomiting for the previous eight days. Four years before admission he began to have pain about one and one half hours after meals, relieved by milk. Examination of the stomach with a barium meal showed a localized area of infiltration with ulceration in the pars media. It was stated that there was a suspicion of malignancy, but that a localized syphilitic infiltration could produce the same picture. An aneurysm of the ascending aorta was also found. The Kahn and Wassermann tests were positive. During antisyphilitic treatment his general condition improved greatly and he gained weight. Upon completion of the first course of antisyphilitic therapy he was completely symptom free.

The authors point out that a positive Wassermann reaction is an almost constant finding in gastric syphilis. On the other hand a gastric lesion in a syphilitic patient is rarely gastric syphilis. All but two of their cases with gastric disease and positive Wassermann reaction had some etiology other than syphilis. They were mostly simple ulcers, carcinomata, or gastritis. The possibility that the various forms of gastric syphilis are merely different evolutionary stages of a single disease is discussed.—*D. S. Kellogg, M.D.*

Royer, M., Croxatto, O., Biempica, L., and Balcázar Morrison, A. J. Biopsia duodenal por aspiracion bajo control radioscopico. (Duodenal biopsy by aspiration under fluoroscopic control). *Prensa méd. argent.*, Aug., 1955., *47*, 2515–2519. (From: Tercera Cátedra de Clinica Médica, Hospital de Clínicas, Buenos Aires, Argentina.)

A method is described for obtaining aspiration biopsy of the duodenal mucosa, and muscularis mucosae, and even the submucosa in some instances. The method is somewhat similar to aspiration biopsy of the gastric mucosa.

By this method histologic confirmation of the presence of normal or inflammatory changes in the duodenal mucosa and submucosa may be obtained. Out of 18 cases, there were 13 considered to be satisfactory for histologic diagnosis.—*Charles M. Nice, Jr., M.D.*

Frimann-Dahl, J. The acute abdomen. I. The value and limitations of radiology in acute abdominal conditions. *Brit. J. Radiol.*, Nov., 1955, *28*, 581–586. (From: Ullevål Hospital, Oslo, Norway.)

Proximity of the roentgenologic department to the surgical department is desirable for maximum consultation between radiologists and surgeons. A close correlation of clinical and roentgenologic information will yield the best results for the benefit of the patient.

Roentgenologic examination of the acute abdomen is of greatest value in acute intestinal obstruction. With the use of barium in all dubious instances, a correct diagnosis can be achieved in 95 per cent of cases, strangulating obstructions being most difficult to diagnose. From the roentgenologic findings one should be able to indicate whether a small bowel obstruction is high or low and it is pointed out that in high obstruction, more common in children, there may be only a few fluid levels and a slight accumulation of gas. Simple obstruction in middle or lower small intestine is often easily diagnosed from plain films alone.

Some cases of strangulating obstruction may show a great resemblance to simple obstruction, but in other cases the scanty findings are characteristic. There may be only a single small fluid level but close scrutiny may reveal a tumor-like density with a polycyclic outline, usually in the lower abdomen. This emphasizes that only sanguinous fluid and very little gas will accumulate in a strangulated loop. The "coffee-bean" sign described by Rigler (the two limbs of a strangulated loop distended by gas and lying in apposition) probably indicates incomplete obstruction with torsion so that some gas enters the loop.

Attempt should be made to diagnose the specific mechanism of the obstruction and even in about half of the cases of volvulus the findings will be diagnostic showing torsion and coil-like arrangment of the dilated loops. At times, the dilated twisted loop may be mistaken for a portion of colon requiring barium enema study for differentiation. The walls of a twisted loop may be discerned converging toward the torsion site. Barium by mouth may also prove helpful at times. In postoperative obstruction or ileus, repeated examinations are important to see whether intestinal distention is diminishing and gas is re-entering the colon or whether loop distention is increasing and no gas is getting into the colon. In doubtful cases, oral barium study is again indicated.

Gas in the biliary tract, evidence of obstruction and a stone somewhere in the abdomen are the well known cardinal signs of gallstone ileus but if the stone is not opaque or cannot be localized, barium by mouth is again the remedy.

Large bowel obstruction is relatively easily detected. A tumor may be observed directly as a defect in the gas column, or a torsion site defined, but barium enema should be used for confirmatory evidence.

In the future, consideration should be given to the possibility of selective angiography in difficult cases of intestinal obstruction.—*H. G. Peterson, Jr., M.D.*

Smith, Rodney. The acute abdomen. II. Radiological help in the diagnosis of abdominal emergencies. *Brit. J. Radiol.*, Nov., 1955, *28*, 586–589. (From: St. George's Hospital, London, S.W.1, England.)

Diagnosis in acute abdominal emergencies is mainly a matter of clinical surgery. There are times when roentgenologic help is being omitted when it might be useful, but there are other times when the reverse is true and films are obtained when a lesion is obvious clinically beyond reasonable doubt.

Roentgenologic help should be thought about in the admitting department and sought if there is doubt about the diagnosis on clinical grounds or if there is doubt about the necessity or urgency of surgery and should never be omitted if some non-operative plan is intended. The examination should be obtained in the radiologic department on the way to the operating room or ward; portable examinations are seldom of a sufficiently good quality to decide a point of differential diagnosis which is difficult on clinical grounds. Time and the energies of the patient should not be wasted in obtaining roentgenographic examination if the diagnosis is already clear.

In perforations and intraperitoneal hemorrhage the clinician really should have arrived at the right answer first, but sometimes roentgenographic examinations may provide the all-important clue. Roentgen evidence is usually not great in torsion of an ovarian cyst or other viscus outside the gastrointestinal tract.

Roentgenographic examination is of maximum value in acute intestinal obstruction of all varieties. Often the precise type of obstruction does not matter very much, but sometimes it decides the treatment and roentgenographic examination may be helpful. The roentgen features of simple small and large bowel obstruction are well known. Strangulation may also be suggested by certain features but their absence does not preclude this possibility.

True paralytic ileus is rare. Any severe trauma may cause it and it is frequently seen in association with renal, biliary or obstetrical pathology or after genito-urinary or gynecologic surgery. Roentgenographic examination is helpful in ruling out mechanical obstruction and in following the progress of intubation and decompression.

Obstruction associated with peritonitis is probably due to adhesions, edema, and kinking as well as to paresis and spasm. The collection of fluid between the loops of bowel is frequently the clue.

Roentgenologic help is of greatest importance in postoperative obstructions when the differentiation between mechanical and paralytic obstruction and the decision to re-operate or treat expectantly can mean the difference between life and death. In general the more sick the patient, the greater is the value of the roentgen examination and again port-

able films should be avoided.—*H. G. Peterson, Jr., M.D.*

Hajdu, Nicholas. The acute abdomen. III. Plain radiography of the abdomen in paediatric practice. Part I. Neonatal period; Part II. Post-neonatal period. *Brit. J. Radiol.*, Nov., 1955, *28*, 590–604. (From: X-ray Department, St. George's Hospital, London, S.W.1, England.)

NEONATAL PERIOD, PART I

Swallowed air appears in the stomach of an infant within five to seven minutes after birth, in the jejunum within one hour, in the proximal colon within three hours and in the rectosigmoid within four to eight hours. The contrast thereby provided by swallowed air permits diagnosis of neonatal gastrointestinal lesions by critical survey of plain films alone in many instances. At twelve hours of age, any failure of gas-filled intestines to occupy the whole available space in the abdominal cavity should raise the suspicion of either intestinal obstruction or a space-occupying lesion.

Five groups, mostly due to developmental errors, constitute the causes of intestinal obstruction encountered in the first few days of life. The first of these groups is failure of recanalization. Esophageal atresia is the most common type but stenosis or atresia may occur at any level in the gastrointestinal tract. Esophageal atresia associated with tracheoesophageal fistula may result in increased gas content of stomach and intestines. Arrested or delayed transport of air from the stomach into small bowel should immediately raise the suspicion of congenital duodenal atresia or stenosis. In complete or nearly complete duodenal obstruction, a characteristic sign is the presence of two separate loculi of gas in the upper abdomen, one in the stomach and the other in the first duodenum. Any procedure which induces the infant to cry will result in sufficient swallowed air to provide contrast.

It may be difficult or impossible to distinguish between intrinsic and extrinsic duodenal obstruction but if the obstruction is complete, the chances are five to one that it is intrinsic atresia. In incomplete obstruction, the chances are about equal between intrinsic and extrinsic. In the second duodenum, a blind end or obstructing membrane is more common whereas in the third duodenum, intrinsic bands are more usual. Barium enema study is important in any such obstruction and if the cecum is shown to lie in the mid-abdomen, the diagnosis of extrinsic obstruction is practically certain.

High jejunal atresia is manifest by a single distended loop of small intestine across the upper abdomen. This appearance indicates fixed dilatation and long-standing hypertrophy of the proximal segment. Adequate surgical correction depends upon recognition of this fact for, unless the entire hypertrophic segment is removed together with the stenosed or atretic one, the hypertrophied segment will remain in ileus for ten days or longer, resulting in obstruction in the same manner as an aganglionic segment. A single fluid level in the stomach can be seen with duodenal and high jejunal atresia as well as with hypertrophic pyloric stenosis. It is well to remember that multiple atretic segments are present in 15 to 18 per cent of the cases and cannot be distinguished roentgenologically from single atresia. The number of gas distended loops in the abdomen will give some indication of how low in the intestine the obstruction is situated.

A second category of developmental errors leading to neonatal intestinal obstruction is failure of mucocutaneous fusion of which imperforate anus is the sole example. This results from a failure of fusion of the hind-gut with the proctodeum. The distance between the anal dimple and the blind end of the colon can usually be demonstrated by a film taken with an opaque object inserted in the dimple and the infant inverted, thereby outlining the blind end with intestinal gas and demonstrating the distance between it and the opaque object in the anal dimple.

Errors of rotation constitute a third group of causes of obstruction. This includes exomphalos, nonrotation with universal mesentery, malrotation and reverse rotation. Complete nonrotation is usually asymptomatic but the others predispose to obstruction from volvulus of the mid-gut, cecum mobile with ileocecal volvulus and congenital bands. More often, however, these do not cause trouble until days or weeks after birth.

A fourth category is failure of secretion which results in meconeum ileus. This occurs in about 20 per cent of cases of pancreatic fibrosis. The obstruction occurs in the distal ileum and is caused by masses of viscid meconium. Atresia of the ileum, perforation and other complications may be present. The roentgen appearance of uncomplicated meconium ileus consists of dilatation of small bowel without abrupt termination and a little gas in the region of the distal ileum where it forms tiny bubbles in the viscid meconium.

The fifth category is failure of nerve supply of which Hirschsprung's disease is the chief example. In the neonatal period, this usually causes symptoms but these may vary from gas distention only with relief following passage of meconium to sustained obstruction with dilatation of small and large intestine. Fixed dilatation and mural hypertrophy develop gradually over a period of weeks or months.

Meconium peritonitis may be a complication of various conditions. In about half of the cases a congenital obstruction is the underlying cause. The roentgen signs are streaky intraperitoneal calcification, free peritoneal fluid and low small bowel obstruction. Only the first first sign is diagnostic.

Duplications of the gut may present as soft tissue

masses in the abdomen or posterior chest. They do not contain gas. They are characteristically associated with occult blood in the stools and when in the chest, may be seen to vary intermittently in size.

Because gas-filled intestines very quickly fill virtually the entire abdomen after birth and any deviation therefrom may be significant, it is suggested that a routine plain roentgenogram of the abdomen at ten hours of age would go a long way in hastening diagnosis before the infant really becomes ill, and thereby reducing mortality.

POST-NEONATAL PERIOD. PART II

After the neonatal period, hypertrophic pyloric stenosis, with a peak incidence in the sixth week, is the condition most frequently encountered and plain roentgenography has nothing to offer in the majority of cases.

Intussusception, accounting for about 50 per cent of all cases of small bowel obstruction in children, is the most important abdominal emergency. On plain film, low small bowel obstruction is the cardinal sign; an interruption or discontinuity in the gas-filling of the colon and a visible soft tissue mass are supporting signs.

As infectious diseases are being brought under control, malformations and tumors assume greater statistical significance. Wilms' tumors are the most common. On the left, these can be easily differentiated from splenic enlargement by the relationship of this mass to the gas-filled colon. Neuroblastomas and retroperitoneal lymphomas are the next most frequent tumors. A diagnosis of neuroblastoma may be made from plain film alone in about 45 per cent of cases, inasmuch as they contain calcification. Chylous ascites may be associated with the late stage of lymphoma.

Differentiation of nephritis with ascites from peritonitis may be possible from plain film. In the former, there is a diffuse opacity in the lower abdomen extending up along the flanks but any gas-containing loops of small bowel are not dilated. In the latter, the abdomen may be filled by dilated loops of bowel separated by exudate.

In appendicitis, the roentgen signs are less important than the clinical findings but frequently there is a localized ileus in the form of moderate gas-filling of a few loops of terminal ileum without dilatation or fluid levels. Fecoliths are more common than in adults.

Intraperitoneal inflammation is frequently manifest by a single gas-distended loop of small bowel with smooth walls adjacent to an ill-defined soft tissue mass. Such a localized ileus is the most important sign of an intraperitoneal abscess, and if treatment is inadequate, the sign of localized ileus waxes and wanes parallel with the clinical findings.

Hematocolpos should be considered in an older girl who presents with a large abdominal soft tissue tumor rising out of the pelvis.

While contrast studies may be indispensable in many cases, much diagnostic information can be gained from proper attention to shadows on plain roentgenograms.—*H. G. Peterson, Jr., M.D.*

MARGULIS, ALEXANDER R., CONKLIN, FRANCES P., NICE, CHARLES M., JR., and RIGLER, LEO G. Deficiency of intestinal gas in infants with diarrhea; a presentation of three cases. *Radiology*, Jan., 1956, *66*, 93–96. (From: Department of Radiology, University of Minnesota Hospitals, Minneapolis, Minn.)

Although the roentgenographic demonstration of a complete absence of gas in the small intestine of infants is commonly interpreted as a sign of high obstruction, the authors have presented 3 cases proving that these findings can be present in infants who have severe diarrhea with dehydration.

Of the 3 cases presented, all have severe diarrhea and dehydration, 2 had no gas in the small intestine and colon, and one showed a deficiency of gas in these organs. The first patient was operated upon, and no obstruction was found. Later, at autopsy, gross examination of the gastrointestinal tract revealed no abnormalities. Culture of the gastric contents and blood revealed coagulase-negative staphylococci, proving that the patient had a generalized infection which was the cause of death. The second patient presented much the same clinical as well as roentgenographic findings. Vigorous antibiotic therapy resulted in complete recovery, and roentgenogram of the abdomen taken three weeks later showed average amounts of intestinal gas. The third patient presented symptoms and physical findings very similar to the other two. Autopsy showed no abnormal findings in the small intestine. The mucosa of the colon, however, was studded with superficial ulcers, and the mesenteric nodes were diffusely enlarged.

The importance of recognizing the picture of the gasless abdomen as a manifestation of diarrhea, vomiting, and dehydration is emphasized, since such knowledge may prevent performance of unnecessary laparotomy. The exact anatomic and physiologic basis for the above described roentgenographic findings is not known, but an explanation is postulated.—*A. Ralph Watson, M.D.*

EYLER, WILLIAM R., and DOUB, HOWARD P. Extraintestinal roentgen manifestations of intestinal lipodystrophy. *J.A.M.A.*, Feb., 18, 1956, *160*, 534–536. (Address: Dr. W. R. Eyler, 2799 W. Grand Blvd., Detroit 2, Mich.)

Intestinal lipodystrophy (Whipple's disease) was first described by Whipple in 1907. The disease was manifested by loss of weight, voluminous fat-containing stools, pigmentation and arthritis. Polysero-

sitis and deposition of fat and fatty acids in the intestinal tissues and mesenteric lymph vessels and nodes were described. Black-Shaeffer demonstrated in 1949 that the pale macrophages, seen in sections of involved material, contained a glycoprotein. Upton confirmed this and described a case with diagnostic histologic changes in a biopsied axillary lymph node.

The roentgen findings in the small intestine are typical of, but not specific, for intestinal lipodystrophy. A coarse mucosal pattern is found with flocculation, clumping and segmentation of the barium column. Roentgen changes in the ankle resembling rheumatoid arthritis have been described.

Four cases of intestinal lipodystrophy are presented in detail. Each case showed the typical deficiency pattern in the small bowel study. Case 1 showed, in addition, a widening of the duodenal loop which proved to be due to a retroperitoneal mass. The mesenteric lymph nodes were also enlarged and the mesentery was thickened. Cases 2 and 3 exhibited changes in the sacroiliac synchondroses characteristic of a Marie-Strumpell type of osteoarthropathy. Case 2 also showed enlarged azygos and right and left paratracheal lymph nodes in the chest roentgenogram. Case 4 showed narrowing of the hip joint spaces.

Roentgen studies of the chest, upper gastrointestinal tract (with special reference to the duodenal sweep and small bowel pattern), and pelvis should be done in cases suspected of having intestinal lipodystrophy.—*Charles W. Cooley, M.D.*

McGEE, ANDREW R., PENNY, STUART F., and WILLIAMSON, NORVAL L. Pneumatosis cystoides intestinalis; with a case report. *Radiology*, Jan., 1956, *66*, 88–92. (From: Toronto East General and Orthopedic Hospital, Toronto, Ontario, Canada.)

This entity rarely occurs in man, but has been sporadically reported in the literature, since DuVernoy described the postmortem findings, in 1738. The greater number of reported cases have been adults, but it has been observed as early as in a 12-day-old infant. Its etiology and pathogenesis have not been proved.

Grossly, single or multiple non-communicating gas-filled cysts of varying sizes up to several centimeters in diameter are found along the intestinal wall, with the small intestine being the most common site. Less frequently, the colon, and rarely the stomach or omentum, are involved. The contained gas is odorless, non-inflammable, and its chemical composition differs greatly from intestinal gas. Microscopically, these subserosal or submucosal sacs are lined by endothelium containing a few giant cells, and the intestinal mucosa appears normal.

Usually this condition is an incidental finding, but it may be related to, or associated with, ulcer, obstruction, or other intestinal pathology. Gastrointestinal bleeding may occur. If the area of involvement is small enough, or complications such as obstruction occur, surgical removal is indicated, since medical management has not been curative.

Roentgenographically, the diagnosis is based on finding gas pockets about the barium column, and pneumoperitoneum may be seen if perforation of these pockets has occurred.

A case report is included.—*Charles L. Stevenson, M.D.*

ALLEN, E. H., BATTEN, J. C., and JEFFERSON, K. Sarcoidosis of the alimentary tract. *Brit. J. Radiol.*, Jan., 1956, *29*, 56–61. (Address: E. H. Allen, St. George's Hospital, London, S. W. 1, England.)

Very few cases of sarcoidosis of the alimentary tract have been reported. The authors found only one case of sarcoid disease of the esophagus in the literature, that described by Kerley in 1950. They noted 22 cases of sarcoidosis of the stomach, including their own case. Five cases of sarcoid disease of the small intestine had been reported. In 1949 Raven published a case of sarcoidosis of the ascending colon, but could find no other case involving the colon described in the literature. The case reported by the authors is the second described, the cecum being involved. Their case showed involvement of the stomach, duodenum, cecum, heart and liver.

Of the 22 cases of gastric sarcoidosis in the literature, the authors discard 8 as being doubtful or unproven. The remaining 14 cases appeared to fall into three roentgenologic groups. The 5 cases in the first group all showed narrowing of the gastric lumen, all having the appearance of scirrhous carcinoma. The second group of 6 cases showed other roentgen changes in the stomach. Four of these had symptoms and evidence of gastric ulcer for which gastrectomy was performed. Microscopic sections showed sarcoid tissue in association with the ulcers. The fifth case in this group was a carcinoma of the stomach in which, on histologic section, granulomatous lesions resembling sarcoid were found among the neoplastic cells and in areas free of the growth. The sixth case showed roentgen evidence suggestive of polyposis of the stomach. On gastroscopic examination the stomach appeared normal, but gastric biopsy demonstrated sarcoid lesions. The third group of three cases were those in which histologic sections of the stomach showed sarcoid tissue. In these, roentgenologic examination of the stomach was normal, gastric resections having been performed because of bleeding.

Considerations in differential diagnosis are discussed. The authors point out in retrospect that involvement of the duodenum as well as the stomach, in their case, should have led them away from the

diagnosis of malignant linitis plastica Photomicrographs and reproductions of roentgenograms are included.—*D. S. Kellogg, M.D.*

Bell, A. L. L., Immerman, Lewis., and Arcomano, Joseph. Body-section cholangiography with a new intravenous medium (cholografin). *Radiology*, Jan., 1956, *66*, 84–87. (From: Department of Radiology, Long Island College Hospital, Brooklyn, N. Y.)

A technique of laminagraphy used by the authors during cholangiography with cholografin is presented. The advantages are as follows: (1) elimination of overlying opaque and nonopaque densities which may be confused with an intraluminal filling defect; (2) demonstration of the intrahepatic and extrahepatic biliary ducts when the contrast of medium within the duct is poor; (3) conclusive demonstration of the presence of calculi within the duct system; and (4) demonstration of the anatomy when surgical procedures on the biliary tract have altered the normal appearance.

Nine roentgenograms are reproduced illustrating these advantages.—*Donald N. Dysart, M.D.*

Walters, Waltman. Postcholecystectomy dyskinesia; with pancreatitis, sphincteritis, and choledocholithiasis as causes. *J.A.M.A.*, Feb. 11, 1956, *160*, 425–431. (Address: Dr. Walters, 200 First St. S. W., Rochester, Minn.)

The following are listed as the most frequent causes of recurring pain following cholecystectomy, especially if stones were present in the gallbladder at the time of surgery: (1) overlooked stones in the common duct; (2) stricture of the bile ducts; (3) remnant of gallbladder with or without stones; (4) elongated cystic duct that is inflammed or contains stones; (5) malfunction of sphincter of Oddi; (6) pancreatitis; (7) intra-abdominal lesions of obstructive or perforating nature; and (8) retroperitoneal lesions.

The preoperative diagnosis may be very difficult even with the aid of laboratory and roentgenologic examination. In most cases the presence of jaundice helps to focus the problem on the obstruction of the biliary tract.

The problem in operating on jaundice patients is to find the cause of obstruction. Operative cholangiography has been of great value in this regard. In the absence of jaundice the problem is more difficult, as there may still be a transient obstruction. Cholangiography has been helpful in these cases also, but to a lesser degree.

The best method for diagnosing chronic pancreatitis is the palpation of a brawny tumefaction of the pancreas, at surgery. It is often difficult to decide whether there is dysfunction of the sphincter of Oddi in the presence of cholangitis, pancreatitis, or both, and what the relationship is between these conditions. Sphincterotomy, choledochoduodenostomy, or a combination of the two procedures have given some success in treatment. The author feels that inflammatory enlargement of the head of the pancreas, narrowing of the pancreatic portion of the common bile duct, or dilatation of the common duct should determine which procedure is the most advisable.

In recent years the author has felt that internal drainage by anastomosing an opening of the common duct to one in the duodenum has been superior to use of a T-tube with external drainage. In some cases where the several methods of drainage together with sphincterotomy or choledochoduodenostomy have failed to relieve the patient's pain, splanchnic nerve blocks with alcohol, or splanchnicectomy, or, in one instance, a cervical chordotomy, have been very effective.

In many instances of postcholecystectomy dyskinesia, abdominal exploration is the only way to determine the presence of a lesion in the biliary tract.—*Kriss M. Kerr, M.D.*

Heuck, F., and Leupold, F. Beobachtungen an den Gallenwegen nach Cholezystektomie. (Observations on the biliary pathways following cholecystectomy.) *Fortschr. a. d. Geb. d. Röntgenstrahlen ver. m. Röntgenpraxis*, Dec., 1955, *83*, 784–792. (From: Medizinische Universitätsklinik, Kiel, Germany.)

The authors analyze the findings in 52 patients examined after gallbladder surgery by intravenous cholangiography with biligrafin (Schering) and more recently with biligrafin forte and report the following observations: Opacification of the common duct after cholecystectomy was observed regularly with both drugs, of the main hepatic ducts more frequently with the newer more concentrated drug, biligrafin forte. Absence of opacification was found in patients with impaired liver function or cholangitis. Moderate dilatation of the common duct was observed frequently in patients after cholecystectomy (in 34 of 52 patients) which is thought to be due to a storage function developed by the choledochus. No obstruction was found in these patients and the common duct showed contraction after a fatty meal. Contraction was noted also in ducts containing concrements but was absent in cholangitis with edema and rigidity of the walls.

The patients were divided into four groups: (1) patients with visible concrements in the biliary ducts; (2) patients with visible deformities of the biliary tree (strictures, kinking, etc.); (3) patients with postcholecystectomy symptoms and normal cholangiograms; (4) patients with anastomosis between the biliary tract and the intestine.

1. Patients with concrements in the common duct show as a rule dilatation of the duct, often with good

contraction after the fatty meal. The dilatation remained visible after removal of the concrements in 3 patients observed by the authors.

2. Narrowing of the common duct due to scarring is sometimes caused by cholecystectomy. One case was observed by the authors where the common duct was severed during operation and end-to-end anastomosis was performed. A narrowing was visible in the cholangiogram, causing no sysmptoms.

Compression of the common duct can be caused by enlarged portal lymph nodes or involvement by a tumor. Kinking at the junction between the intra- and extrahepatic portion of the biliary tree can be due to loop formation of the common duct which is not pathologic or due to scarring. Pneumoperitoneum has helped frequently in the differential diagnosis by demonstrating adhesions at the porta hepatis. A stump of the cystic duct might be difficult to distinguish from a diverticulum of the common duct.

In patients with double gallbladder, after removal of one gallbladder, the remaining one can become opacified and can be mistaken for a dilated stump of the cystic duct. Retrograde opacification of the duodenal bulb must not be mistaken for a dilated stump of the cystic duct. In case of doubt, a barium meal is useful.

A narrow pointed lower end of the common duct was found in symptom-free patients and should not be considered a sign of spasm of Oddi's sphincter. Rapid excretion of radiopaque bile (10 minutes after injection) is not a sign of insufficiency of the sphincter.

3. Postcholecystectomy symptoms in patients with normal cholangiograms are thought to be due to abnormal function of the autonomous nervous system. In same patients deformities of the duodenum were demonstrated and it is suggested that these might be the cause of their symptoms.

4. In patients with choledocho-or cholecystoduodenostomy, no opacification of the biliary tree was demonstrated except in one case. The radiopaque bile enters the duodenum and is visible in its lumen. Opacification of the biliary tree in these patients was obtained after peroral administration of barium.—*Karol E. Matzinger, M.D.*

Wapshaw, Henry. Radiographic and other studies of the biliary and pancreatic ducts. *Brit. J. Surg.*, Sept., 1955, *43*, 132–141. (Address: Western Infirmary, Glasgow, Scotland.)

Postoperative cholangiography was performed in 56 patients, of whom 48 had primarily biliary disease, and 8 primarily pancreatic disease. All but 4 were examined in accordance with the technique described by both Bockus and Buckstein, and examinations were done between the 8th and 10th postoperative days. Four cases were examined in the operating room at time of surgery.

The course of the ducts varies considerably in different individuals and 5 principal duct patterns were recognized. The knowledge of the course is of some value in treatment of the benign strictures.

Reflux into the main pancreatic duct occurred in 7 of the 50 cases, or 14 per cent. In a collective study of 1,521 cases, the incidence of reflux was 33.5 per cent. Causes of such reflux are stones, stricture, or spasm at the herniation of the common bile duct. For reflux to occur as a result of spasm of the sphincter of Oddi, it is necessary that the common bile duct and duct of Wirsung join proximal to the duodenal wall, and this is the case in only 2 per cent of normal individuals.

Concerning the role of reflux of bile into the pancreatic duct in the production of acute pancreatitis, all previous statistical studies of anatomic relations have been made in normal patients and cadavers. In this regard the present series of 7 patients with acute pancreatitis is of interest. Three of these (42.8 per cent) showed reflux into the pancreatic duct whereas only 7 of 48 patients (14.5 per cent) with biliary disease showed reflux.

Morphine was given in $\frac{1}{4}$ gr. doses to 25 subjects in an attempt to cause reflux into the pancreatic duct. There was no demonstrable effect in 5 patients. In the remaining 18 (78.3 per cent) within 5 minutes of injection the terminal part of the common bile duct was compressed to such a degree as to completely obstruct the duct, and this constriction lasted from four minutes to two hours. In only one of these cases could it be said that the morphine caused pancreatic reflux. Where reflux had occurred prior to injection, the transduodenal segments of each duct were compressed, thus dissociating the ducts. There was no indication as to whether this action of morphine is directly on the sphincter of Oddi or on the duodenal musculature.

Overlooked stones were demonstrated in 5 cases, 2 of which were done by immediate cholangiography at the time of surgery.

In 7 cases of pancreatitis no overt evidence of compression of common bile duct was demonstrated. There was stenosis in one case of annular pancreas and also in one case of papilloma of the common bile duct.

Artefacts encountered were principally irregular filling due to air bubbles, high viscosity of medium, inadequate quantity of medium, blood clot, bile, fibrin or organic debris. Occasionally a blocked drainage tube or long cystic duct stump may be confusing.

One patient with pancreatitis developed epigastric pain and near collapse following cholangiography, and this cholangiogram showed reflux into the pancreatic duct. The patient recovered. It was the impression of the author that the reaction was due to overfilling of the gallbladder rather than to pancreatic embarrassment.

Object lessons to be observed are: (1) forceful injection is to be avoided especially in the presence

of a distal obstruction, (2) cholangiography in the presence of an isolated infection of biliary tract is fraught with danger.—*Lois Cowan Collins, M.D.*

Gynecology and Obstetrics

Schwarz, Gerhart S. A device for measuring circumferences on roentgenograms. *Radiology*, Jan., 1956, *66*, 97–100. (From: Department of Radiology of the College of Physicians and Surgeons, Columbia University, and the Radiological Service of the Presbyterian Hospital, New York, N.Y.)

In order to measure the circumference of the fetal head on roentgenograms more accurately and simply, the author has employed a flexible plastic ruler formed into a loop. The details of its inexpensive construction are given.

The device has also been used to measure the volume capacity of the pelvic inlet for a sphere, and has been shown to be more reliable than obtaining the volume from the smallest inlet diameter, especially for the android pelvis.

It is being used at Presbyterian Hospital in New York City, for all wet film readings in fetometry and cephalopelvimetry, in conjunction with the Ball method.—*Charles L. Stevenson, M.D.*

Genitourinary System

Iannaccone, Guido, and Panzironi, Paolo Emilio. Ureteral reflux in normal infants. *Acta radiol.*, Dec., 1955, *44*, 451–456. (From: Institute of Medical Radiology, University of Rome, Rome, Italy.)

Fifty normal infants were examined for vesico-ureteral reflux and the condition was found in 1 case. The infants varied in age from ten days to six months.

Ureteral reflux from the bladder usually occurs when the vesico-ureteral valve mechanism is impaired and the intravesical pressure is greater than the pyelo-ureteral pressure. Vesico-ureteral reflux is prevented in normal subjects by: (a) ureteral tonus and contractions, (b) the length and obliquity of the intramural portion of the ureter which is compressed during vesical contractions, and (c) the existence of a small mucosal valve "leaf" at the ureteral-vesical junction.

The authors' case showed: (a) unilateral reflux, (b) normal ureters and pelves, (c) quick disappearance of the medium and (d) presence of reflux in only 1 of 3 examinations. Pathologic cases usually showed: (a) bilateral reflux, (b) dilated atonic ureters and pelves, (c) longer duration of the reflux and (d) reproducibility of the reflux.

Vesico-ureteral reflux in normal infants was explained by the rapid and marked intravesical pressure taking place during the short time that the rhythmic opening of the ureters occurred. The intravesical pressure is increased more in infants during coughing and crying as it is partially intra-abdominal.

It is concluded that vesico-ureteral reflux rarely occurs in normal infants.—*Charles W. Cooley, M.D.*

Stewart, Charles Montgomery. Delayed cystography and voiding cystoureterography. *J. Urol.*, Dec., 1955, 74, 749–759. (Address: 2010 Wilshire Blvd., Los Angeles 57, Calif.)

The author presents some seven years' experience with these two procedures and finds that they are invaluble in certain instances of urinary tract disease.

He uses urokon in a concentration of 18–20 per cent, slightly warmed prior to injection, and is careful not to overdistend the bladder. Films are exposed immediately following instillation and at fifteen to thirty minute intervals thereafter over a period of three hours.

Voiding cystoureterographic studies are made at the termination of the delayed cystographic series or immediately after the instillation of contrast medium. The patient stands in the erect position and the film is exposed while the patient is forcibly voiding. If the patient is too young to cooperate the bladder is slightly overfilled, the catheter is then removed and the film is exposed while the child strains to void.

It has been found that the degree of overdistention bears no relation to the reflux into the ureters and that overdistention is not necessary for a demonstration of reflux during delayed cystography or voiding cystoureterography.

The type of reflux demonstrated in these patients does not occur in the normal urinary tract. In some instances the exact cause for its appearance cannot be determined and it is impossible to predict the reflux competence of a ureteral orifice on the basis of a cystoscopic appearance or on the basis of intravenous or retrograde pyelograms.

The causes of reflux may be urinary tract infection, neurogenic defects, structural or functional variations from the normal, and acquired obstructive uropathies. In some instances it has been noticed that the ureteral reflux persists even after the initiating mechanism has been corrected.

The author concludes that cystography, delayed or voiding, provides certain diagnostic information which is unobtainable by any other method.—*George W. Chamberlin, M.D.*

Henson, Stanley W., Jr., and Coventry, Mark B. Osteomyelitis of the vertebrae as the result of infection of the urinary tract. *Surg., Gynec. & Obst.*, Feb., 1956, *102*, 207–214. (From: Department of Surgery and Section of Orthopaedic Surgery, Mayo Clinic and Mayo Foundation, Rochester, Minn.)

The authors believe that osteomyelitis of the vertebrae is not as rare as is generally assumed and that infection of the urinary tract is an important primary focus. Over half the reported cases of osteomyelitis were in the lumbar region and one quarter involved the thoracic region. The onset of symptoms may be abrupt and the course fulminating, or it may be insidious and the course slowly progressive. In mild cases spontaneous recovery may occur.

Satisfactory roentgenograms are one of the most important factors in making the diagnosis. Special anteroposterior, lateral and oblique views centered over the point of maximum pain frequently show evidence of such a lesion after routine films have failed to reveal it. However, pain and rigidity may have been present for months before a lesion can be demonstrated. The earliest changes are rarefaction and loss of trabecular detail. Later there may be fuzziness along the upper or lower bony plates or collapse of the vertebra. Narrowing of the intervertebral disk may occur and it may precede any demonstrable bone involvement. The differential diagnosis includes tuberculosis, brucellosis, fugi and salmonella infections as well as myeloma, metastatic carcinoma and other malignant lesions.

When the lesion can be accurately localized, it is felt that needle biopsy under roentgenologic control should be performed for culture and sensitivity studies. Many months, and even years of pain and sometimes permanent disability can be avoided by the timely use of such biopsy procedures.

Seven cases of osteomyelitis of the spinal column in urinary tract infections are reported by the authors. The delay from the onset of back pain until diagnosis averaged four months.—*Arthur E. Childe, M.D.*

Skeletal System

Ravelli, A. Zur Ossifikation der Vieleckbeine. (Ossification of the multangular bones.) *Fortschr. a. d. Geb. d. Röntgenstrahlen ver. m. Röntgenpraxis*, Dec., 1955, *83*, 852–854. (From: Zentralröntgeninstitut der Universität, Innsbruck, Austria.)

Besides the normal uninuclear ossification of the multangular bones, there is, in extremely rare cases, also a binuclear and a unilocular bicentric variety.

To the only case in the literature, described by Rückensteiner, the author adds 2 cases. The first is a case of a six year old boy, where the roentgenogram showed bifocal ossification of both multangular bones and of the semilunar. The second is a case of a six year old girl, where the roentgen study revealed bifocal ossification of the greater multangular bone. —*Hans Lewin, M.D.*

Collins, Vincent, P., and Collins, Lois C. Benign conditions simulating bone tumors. *J.A.M.A.*, Feb. 11, 1956, *160*, 431–436. (Address: Dr. V. P. Collins, 1200 M. D. Anderson Blvd., Houston, Texas.)

While every effort must be exerted to recognize malignant bone lesions at the earliest possible moment, the authors emphasize that it is at least equally important to recognize benign lesions as such and to avoid, if possible, the mental trauma which the patient may suffer from protracted cancer investigations and the disaster occasioned by unnecessary radical treatment. Clinical, pathologic, and roentgenologic evidence should be taken together, so that the diagnosis may be established beyond reasonable doubt.

The categories into which benign conditions of bone are divided are: (1) variations of normal roentgen appearances, which include normal structure, "roughening" or "abrasion" of posterior aspect of lower end of femur, and double cortical contour; (2) developmental abnormalities, which include cortical defects, nonosteogenic fibroma, bone cyst, fibrous dysplasia and aseptic necroses; (3) traumatic lesions, which include occult trauma, fracture, periosteal injury and myositis ossificans; (4) metabolic disorders, such as lipid storage disease, vitamin deficiency, hyperparathyroidism, and Paget's disease; (5) infection due to pyogens, lues or mycosis; (6) inflammation, including benign cortical hyperostosis, osteoid osteoma, osteitis pubis and hypertrophic pulmonary osteoarthropathy; and (7) benign tumors of bone, especially benign giant-cell tumor, chondroma and chondroblastoma.

The authors conclude that examination of the entire skeleton, with the advantage of clinical information, and, if possible, an opportunity to note any change in roentgen appearance over an interval of time, will aid in prompt recognition of benign bone lesions and prevention of unnecessary radical treatment.—*Henry J. Teufen, M.D.*

Valls, José, Schajowicz, Fritz, Valls, Jorge E. (Buenos Aires, Argentina). Tumores de la serie cartilaginosa. (Tumors of the cartilaginous series.) *Rev. ortop. y traumatol., Latinoamericana*, 1955, N. S. *1*, 3–27.

This material is based on a study of 165 tumors of the cartilaginous series. The tumors are classified as follows:

(A) *Benign tumors*
- I Solitary
  - 1. Chondroma
    - a. central (enchondroma)
    - b. periosteal
    - c. calcifying and ossifying
  - 2. Epiphyseal chondroblastoma
  - 3. Osteochondroma (osteogenic exostosis)
- II Multiple
  - 1. Multiple chondromas
  - 2. Multiple enchondromatosis (Ollier's dis-

ease or dyschondroplasia)
3. Multiple exostoses (osteogenic disease or deforming hereditary chondrodysplasia)
4. Articular osteochondromatosis

(B) *Malignant tumors*
1. Primary chondrosarcoma
2. Secondary chondrosarcoma
3. Chondro-osteogenic sarcoma

Chondromas of the hand and foot were unfirmly benign in 37 cases. In the ribs, sternum, ilium, femur, tibia and humerus the prognosis is more reserved.

The epiphyseal chondroblastoma (Codman) arises during adolescence in the epiphysis of the upper humerus, lower femur, upper tibia and occasionally in other epiphyses. The tumor is primarily osteolytic with zones of partially calcified cartilage. The process is usually benign but malignant evolution is known to occur.

Chondrosarcomas are uncommon and appear between the ages of twenty to forty years. Evolution is gradual and metastases occur later, giving this tumor a better prognosis than in osteogenic sarcoma. Of 27 chondrosarcomas 19 were primary and 8 were secondary to other benign cartilaginous tumors.

Chondro-ostegenic sarcomas, noted in 3 cases, are formed by cartilaginous tissue which contains zones of tumoral osseous neoformations. The evolution is more favorable than in osteolytic osteogenic sarcoma.—*Charles M. Nice, Jr., M.D.*

Barrett, N. R. Primary tumours of rib. *Brit. J. Surg.*, Sept., 1955, *43*, 113–132. (From: St. Thomas's Hospital, London, England.)

On the basis of experience gained from seeing and treating 50 patients with primary tumors of rib, the author discusses these rib tumors under the following classifications: (1) Multiple exostosis, (2) cartilaginous tumors, (3) other tumors, including fibrous dysplasia, lipoid granuloma, myeloma and osteoclastoma.

In differential diagnosis the first caution is not to mistake a developmental variant of the costal cartilage with a chondroma. Occasionally the congenital faults of the ribs themselves may cause puzzling appearances.

Biopsy (with an adequately large specimen) is urged, principally to differentiate between groups of lesions whose treatment may be different. Particularly this differentiation should be made between cartilaginous tumors which should be excised and fibrous dysplasias and lipoid granulomas which can be safely treated conservatively, and chronic inflammatory diseases and metastases.—*Lois Cowan Collins, M.D.*

Moseley, John, E., and Bass, Murray H. Sclerosing osteogenic sarcomatosis; a radiologic entity. *Radiology*, Jan., 1956, *66*, 41–45. (From: Department of Radiology, The Mount Sinai Hospital, New York, N. Y.)

The authors report a case of sclerosing osteogenic sarcomatosis adding to the 3 previously reported cases in the literature.

The striking, bizarre, and easily recognizable roentgenographic features are practically identical in these 4 cases. Multiple areas of dense new bone formation are present throughout the skeletal system. In the long and short tubular bones, the sclerotic process has a marked predilection for the metaphyses. There is similar involvement of the ribs, clavicles, numerous round and flat bones, the vertebrae, and several epiphyses. Areas of soft tissue calcification may be evident. In some regions, the process is limited to the bone, while in others it perforates the cortex and extends into the subperiosteum or adjacent soft tissue.

All these patients were young persons whose bones were in an active stage of growth. Nothing in the history or physical findings suggested a predisposing or underlying cause. The course of the disease in each instance was extremely rapid.—*Donald N. Dysart, M.D.*

Bunim, Joseph J. Arthritis in the elderly patient (osteoarthritis). *Bull. New York Acad. Med.*, Feb., 1956, *32*, 102–115. (From: National Institute of Arthritis and Metabolic Disease, National Institutes of Health, Bethesda, Md., and Johns Hopkins University, Baltimore, Md.)

Osteoarthritis, otherwise referred to as degenerative joint disease, hypertrophic or senescent arthritis, is a structural disease of joints which may develop spontaneously with advancing age (primary arthritis) or at any period of life as a sequel to mechanical injury, deformity, infection or any other condition that leads to degeneration of articular, hyaline cartilage (secondary osteoarthritis). A combination of two factors is involved in the pathogenesis of osteoarthritis. The primary factor leads to degradation of articular cartilage and the secondary one usually consists of superimposed mechanical or functional stress (such as weight bearing or excessive motion) or prolonged nutritional deficiency of the cartilage. In the spontaneous type, the primary factor is believed to consist of senescent changes in the cartilage.

Degenerative joint disease is the most common type of chronic arthritis. The site of involvement which gives rise to symptoms in order of descending frequency is: spine 73 per cent, knees 25 per cent, hips 7 per cent and other joints 5 per cent.

The first step in the chain of pathological events is degeneration of the joint cartilage. The secondary changes that follow in response to cartilage injury are productive or hypertrophic in nature. This

further impairs the articular function. Every structure of the joint often participates in this reaction: the calcified cartilage, the subchondral bone, the synovial lining and the capsule.

In the pathogenesis of osteoarthritis, the productive phase—which includes reduplication and thickening of the calcified lamella, eburnation of subchondral bone, proliferation of osteophytes and fibrosis of the capsule—occupies an intermediate stage between the initial phase of cartilage degeneration and the final period of osseous destruction. As a result of ischemic changes that occur in the advanced stages, small areas of aseptic necrosis of bone develop. Multiple bone cysts also appear.

The two most common types of chronic joint disease that are encountered in middle-aged and elderly patients are osteoarthritis and rheumatoid arthritis. The basic difference is that rheumatoid arthritis is inflammatory while the osteoarthritis is a degenerative disease.

The author gives a detailed account of the incidence, history, sequence of pathological events, factors that contribute to development of osteoarthritis, clinical features and diagnosis and treatment of osteoarthritis.—*Peter C. Truog, M.D.*

McEwen, Currier, Poppel, Maxwell H., Poker, Nathaniel, and Jacobson, Harold G. Protrusio acetabuli in rheumatoid arthritis. *Radiology*, Jan., 1956, *66*, 33–40. (From: Departments of Radiology, Hospital for Special Surgery, New York Hospital-Cornell Medical Center, and the New York University College of Medicine, New York, N. Y.)

Protrusio acetabuli (arthrokatadysis, Otto pelvis) is "an affection of the hip joint characterized anatomically by deepening of the acetabulum with mesial displacement of the inner wall." Two types of cases are recognized: (a) Those in which no evidence of focal hip disease is present and in which protrusion is bilateral; (b) cases in which primary focal hip disease is present and in which the protrusion is usually unilateral. A wide range of etiologic factors may be responsible for this condition. There is general agreement that this is a syndrome rather than a disease entity. Whenever a disease process involves the acetabulum, protrusion may result as a result of a boring effect of the intact femoral head. Rapid severe destructive processes involving both the acetabulum and the femoral head lead to bony ankylosis; conditions which produce localized acetabular decalcification are likely to result in protrusion.

Pain and limitation of motion are common symptoms. There is limitation of abduction, with shortening of the involved extremity. A flexion deformity of the involved hip is not unusual. Frequently there is an increase in the lumbar lordosis and a "waddling gait."

Roentgenograms of the hip are required to detect early stages of protrusion and to determine the extent of the changes. The protrusion varies in extent from a few millimeters to 5 cm. The acetabulum migrates upward, inward and forward, projecting into the pelvis as a dome-shaped mass. The femoral head is usually preserved. The trochanters approach the pelvic margins resulting in limitation of motion.

The authors studied 100 patients with rheumatoid disease of the hip and found 5 cases with protrusion, an incidence of 5 per cent. An additional 3 cases were personally observed. It is likely that minimal protrusions may frequently go undetected and it becomes the responsibility of the radiologist to alert all concerned to this finding in rheumatoid arthritis.—*Arno W. Sommer, M.D.*

Steinbach, Howard L., Petrakis, Nicholas L., Gilfillan, Rutherford S., and Smith, Donald R. The pathogenesis of osteitis pubis, *J. Urol.*, Dec., 1955, *74*, 840–846. (From: Departments of Radiology, Medicine, Surgery, Urology, and the Cancer Research Institute, University of California Medical School, San Francisco, Calif.)

The authors discuss the various etiologic mechanisms which have been considered; namely, trauma, infection and impaired circulation. In an effort to evaluate the latter etiologic factor they have injected a water-soluble contrast medium into the venous sinusoids of the pubic bone in patients after uncomplicated retropubic and suprapubic prostatectomy and in postoperative patients with osteitis pubis. Following such injection in a normal individual the opaque material can be seen passing rapidly through the pubis through multiple small veins which drain into the pudendal, vesical and prostatic venous plexuses, and then to the obturator, inferior gluteal, and hypogastric veins. Where there is no venous obstruction, the drainage is rapid and the larger pelvic vessels are visible within two seconds after the completion of the injection. In two patients who had osteitis pubis this injection showed evidence of venous stasis. In one case there was partial obstruction to the flow of the opaque medium into the adjacent veins and in the other case there were very large dilated channels within the periosteum of the pubic bones on both sides of the midline. The position of the cortical defects usually seen between the symphysis and the medial aspects of the inferior rami of the pubis suggested that they were due to erosion by the dilated venous channels situated between the cortex and periosteum.

The authors note that two factors remain to be explained: (1) The cause of the venous obstruction. This could be due to the surgical procedures or to thrombophlebitis as a result of trauma to the pelvic vessels. (2) The presence of microscopic evidence of inflammation and bacteriologic evidence of infection

needs to be clarified. These organisms are not ordinarily considered as pathogenic, but under certain circumstances, such as the presence of venous stasis and devitalized tissues in the host, may be capable of producing low-grade inflammatory reaction.

Eight roentgenographic reproductions illustrate the normal and abnormal changes associated with osteitis pubis.—*George W. Chamberlin, M.D.*

Nervous System

Tarazi, Antone K., Margolis, George, and Grimson, Keith S. Spinal cord lesions produced by aortography in dogs. *A.M.A. Arch. Surg.*, Jan., 1956, 38–47. (From: Departments of Surgery and Pathology, Duke University School of Medicine, Durham, N. C.)

Serious complications may occur as frequently as 1 in each 50 patients studied by aortography. The more serious of these seem to be directly related to a high concentration of the contrast medium at the origin of the mesenteric, renal and spinal arteries.

The authors report the use of sodium acetrizoate (urokon sodium) and iodopyracet (diodrast) in a deliberate attempt to produce spinal cord injury in dogs weighing between 15 and 42 pounds. It was found that 15 cc. of 70 per cent sodium acetrizoate injected rapidly through an aortic puncture site just below the renal arteries would uniformly produce paraplegia in supine dogs. No paraplegia developed in one half of the dogs injected in a similar manner with 70 per cent iodopyracet. The iodine content of the latter is 49.8 per cent in distinction to that of acetrizoate which is 65.8 per cent.

All subsequent experiments were carried out with acetrizoate. Injections in 9 dogs at a point above the superior mesenteric artery produced spastic paraplegia in 2, spastic paraparesis in 4 and no apparent abnormality in 3. When injections were made into the midthoracic aorta, 2 out of 4 dogs suffered no apparent injury, 1 developed paraplegia and 1 slight paraparesis in one leg. When only 7 cc. of contrast medium were injected spinal cord injury was less frequently produced.

The spinal cord of the dog extends to the seventh lumbar vertebra and is consequently more susceptible to injury by contrast media than the spinal cord of man, which ends at the first lumbar vertebra. The level of the segment of injury of the spinal cord in the dog was usually higher than the level of injection into the aorta. This was demonstrated by roentgenograms made during injection which showed that the radiopaque material during forcible injection rose within the lumen of the aorta several centimeters against the blood flow. The fact that injections above the superior mesenteric artery or in the midthoracic aorta caused less injury than injections made below the renal arteries may relate to the diversion of part of the contrast material into the renal and mesenteric arteries.—*Arthur E. Childe, M.D.*

Horwitz, Norman H., Whitcomb, Benjamin B., and Reilly, Francis G. Ruptured thoracic discs. *Yale J. Biol. & Med.*, Dec.–Feb., 1955/6, *28*, 322–330. (From: Department of Neurosurgery, Hartford Hospital, Hartford, Conn.)

The authors report 5 cases of typical ruptured thoracic intervertebral disks. They are of two types: (1) those producing cord pressure with long tract signs, and (2) those more laterally placed, producing root pressure with radicular signs and symptoms.

The myelogram was positive and there was a definite elevation of the protein content in the spinal fluid in all of the cases. The elevation was higher than usually seen in lumbar or cervical ruptured disks. A definite history of trauma was present in 2 cases and was probably present in another case. One of the ruptured disks was at D1–2, one at D7–8, two at D9–10 and one at D11–12. In two instances the preoperative diagnosis was probable tumor. These two cases had cord compression and long tract signs. The other three cases had root compression with radicular signs.

Excellent results were obtained in all cases following surgery.

The possibility of ruptured disk of the thoracic area as a cause of unexplained pain in the thorax and abdomen is suggested.—*Peter C. Truog, M.D.*

Blood and Lymph System

Bonte, Frederick J., Weisberger, Austin S., and Piavello, Carlo. An evaluation of portal venography performed by intrasplenic injection of contrast material (splenography). *Radiology*, Jan., 1956, *66*, 17–23. (From: Departments of Radiology and Medicine, Western Reserve University School of Medicine and University Hospitals of Cleveland, Cleveland, Ohio.)

Observations on splenography (intrasplenic portal venography) in 18 patients with special reference to indications, techniques involved, risks incurred, and results obtained are presented. Any patients with splenomegaly of unknown origin is a candidate for diagnostic splenic puncture, and theoretically any candidate for splenic puncture is a candidate for splenography. After splenic puncture had been performed and a specimen of splenic pulp obtained by aspiration, 20 to 40 cc. of 70 per cent diodrast or 70 per cent urokon was injected rapidly into the spleen and exposure of films at intervals of a half second to two seconds begun when approximately one-fourth of the contrast material had been intro-

duced. Care must be taken to avoid fixation of the needle during the procedure, since this is probably the leading single cause of the most feared complication of the examination—rupture of the spleen. This complication occurred in one patient in this series necessitating emergency splenectomy a few hours later.

Splenography affords the best possible demonstration of esophageal varices short of portal venography performed during laparotomy, and occlusion of the portal venous system by thrombosis or extrinsic pressure can also be demonstrated. In any individual case, however, the need for splenography must outweigh the risk of rupture of the spleen, as well as the ever-present possibility that a diagnostic record may not be obtained. The examination was unsatisfactory in 10 of the 18 patients in this series.—*Harold C. Hamilton, M.D.*

General

King, J. Cash. Trauma to the abdominal and retroperitoneal viscera as it concerns the radiologist. *South M. J.*, Feb., 1956, *49*, 109–119. (From: Departments of Radiology of the University of Tennessee College of Medicine, and the Methodist Hospital, Memphis, Tenn.)

This paper is based on the study of 61 cases in which injury occurred to one or more of the following organs as follows: Spleen, 20; liver 14; pancreas, 3; kidney, 27; diaphragm, 4; intestine, 4.

The author found that the greatest difficulty was encountered in making an accurate diagnosis in cases of nonpenetrating trauma. The mortality rate was also 20 to 30 per cent higher in these cases than where penetrating injuries had occurred and an indication for an abdominal exploration already existed.

He suggests that one classification can be applied to all injuries of the solid viscera. This is as follows: (1) large transcapsular tears; (2) smaller lacerations and contusions; and (3) subcapsular injuries.

By using this classification it was possible to devise a pattern which the radiologist can use in studying all cases of trauma in the mid-trunk region. Such a pattern would be as follows:

1. Skeletal injuries.
2. Changes in size or contour of the affected organ;
   (a) Enlargment
   (b) Deformity
   (c) Loss of sharp delineation.
3. Evidence of bleeding into an adjacent space (peritoneal cavity or retroperitoneal space):
   (a) Displacement of adjacent visceral structures
   (b) Homogeneous density adjacent to the affected organ
   (c) Accumulations of fluid between gas-filled intestinal loops
   (d) Increased overall density (peritoneal cavity or retroperitoneal space)
   (e) Fluid adjacent to extraperitoneal fat layer in flank.
4. Changes in other organs:
   (a) Altered position, contour or movement of the diaphragm
   (b) Ileus or other gaseous distention of the gastrointestinal tract.

The minimal roentgen examination required for such a study would be films of the chest, preferably in the upright and supine positions, and films of the abdomen in the supine and either in the upright or lateral decubitus positions.

The author concludes that the radiologist can be of assistance in the early diagnosis of visceral injuries, but his usefulness on the diagnostic team is in proportion to his knowledge of clinical medicine as well as good roentgenologic procedures.—*Peter C. Truog, M.D.*

RADIATION THERAPY

Garciga, C. E. Tumores malignos de los párpados. (Malignant tumors of the eyelids.) *Arch. cubanos cancerol.*, Oct.-Dec., 1955, *14*, 463–468. (From: Instituto del Rádium, Hospital "Nuestra Senora de las Mercedes," Habana, Cuba.)

Between 1940 and 1950 there were 242 cases of malignant tumors of the eyelids at the Instituto del Rádium and Hospital Curie, Havana, Cuba. Ninety-five per cent occurred in white people and only 5 per cent in Negroes and mulattos in spite of the high percentage of colored people in the Cuban population. Fifty-six per cent were located in the lower eyelid, 16 per cent in the upper eyelid, and 22 per cent at the inner canthus. Localization of the remaining 6 per cent was not recorded. It is to be noted that there were no tumors of the outer canthus. A pathologic diagnosis was available in 195 cases; 85 per cent were basal cell and 12 per cent epidermoid carcinomas; there were 4 adenocarcinomas, one melanoma, and one sarcoma.

Assessment of therapeutic results was hampered by lack of adequate follow-up in 76 patients. Of the determined cases roentgentherapy and radium therapy controlled about 60 per cent and electrocoagulation controlled 51 per cent. Some tumors were treated with a combination of two therapeutic agents; sometimes this was the original plan from the outset; occasionally one kind of treatment was given after another one had previously failed. Combination of electrocoagulation plus roentgen therapy gave 20 per cent cures, electrocoagulation plus radium therapy 70 per cent, and roentgen plus radium therapy 70 per cent of the cases so treated.

The best prognosis was in carcinoma of the lower eyelid with 60 per cent cures, followed by lesions of

the inner canthus with 58 per cent; tumors of the upper eyelid yielded a cure rate of 39 per cent. No surgical results are reported.—*F. Comas, M.D.*

Cantril, Simeon T. The care of the patient with advanced cancer of the breast. *Radiology*, Jan., 1956, *66*, 46–54. (From: Tumor Institute of the Swedish Hospital, Seattle, Wash.)

Prognosis in cancer of the breast is largely determined by:

(a) the local growth and metastasizing tendency of the cancer
(b) the stage of pathologic spread when the patient is first seen, and
(c) the effectiveness of initial and subsequent treatment.

Therapy is, therefore, concerned with the choice of the agent best suited to the individual case, in view of the relative malignancy and extent of the disease.

Of all breast cancer patients examined in large centers, about 60 to 75 per cent are considered operable and are treated by radical mastectomy. Of the patients subjected to radical mastectomy, about 60 per cent will show evidence of axillary metastases. About one-third of these will survive five years. The remaining two-thirds are unrecognizably inoperable or advanced, since radical surgery does not arrest the disease. If the latent advancement in these failures could be detected beforehand, it would be possible to omit radical operations, doomed to failure at the outset.

Irradiation of inoperable breast cancer is a procedure of sufficient magnitude that the patient's age, general condition and relative freedom from distant spread must be appraised in relation to the anticipated palliation. In general, the procedure includes irradiation of regional lymphatic spread, thus requiring multiple fields and minimal protraction of six or eight weeks. Avoidance of pulmonary reactions requires tangential fields. When protraction was extended for as long as twelve to sixteen weeks, 38 of 109 patients (34 per cent) survived and were clinically well for five years. With long protraction and meticulous care, it is possible to administer a dose within the breast and regional lymphatics of 5,000 to 6,000 r minimum.

Massive residual disease at the operative site is difficult to control by any method. Treatment of the entire affected area with an effective dose is obviously impractical. We must, therefore, compromise, treating individual or contiguous groups of metastases with low voltage irradiation such that a dose of 4,000 to 5,000 r can be given in a period of a week or less.

Irradiation for the control of pain from bone metastases is probably the radiologist's most significant contribution to the management of carcinoma of the breast. A relatively small dose may relieve pain or even promote bone healing. Treatment is best adapted to the individual situation. Doses may be as high as 2,000 to 3,000 r in two to three weeks.

Widespread skeletal metastases in the patient who is still ambulatory may well be treated by some form of hormonal therapy (castration or hormonal medication) with irradiation of limited areas where fracture may appear imminent. Favorable results with radiophosphorus have been reported. Total doses were of the order of 15 to 20 mc given in increments of 2 mc over forty or more days.

The use of radiogold and radiochromic phosphate for reducing pleural effusion of metastatic origin deserves a trial in patients who require frequent thoracenteses.

It is possible, as concepts change, that irradiation may come to play a greater role than at present, yet its limitations must be recognized without losing sight of its potentialities for effective palliation.—*Arno W. Sommer, M.D.*

Comas Mutierrez, Gaston. Cancer de la tráquea. (Carcinoma of the trachea.) *Arch. cubanos cancerol.*, Oct.–Dec., 1955, *14*, 483–506. (From: Instituto del Rádium, Hospital "Nuestra Senora de las Mercedes," Habana, Cuba.)

The rarity of tracheal carcinoma is attested by the statistics of the Instituto del Rádium, Havana, Cuba where in the last 30 years there were 1,196 laryngeal and bronchial tumors; in the same period of time only 3 cases of carcinoma of the trachea were observed. All three occurred in white middle-aged men. Two of them were epidermoid carcinomas, located near the bifuraction of the trachea, well advanced when first seen with symptoms of tracheal and superior vena cava obstruction, and showing mediastinal and supraclavicular metastases. Both were irradiated by means of external roentgen therapy but the treatment could not be completed in either case. Both died within a short time after the initial examination, little palliation having been obtained.

The third case was that of a man with hacking cough, exertional dyspnea, and dysphagia of 8 months' duration. Bronchoscopy and laminagraphy revealed an extensive tumor infiltrating the lower third of the trachea and occluding its lumen almost entirely, but no regional or distant metastases were detected. The pathologic diagnosis was malignant mixed salivary gland tumor. Roentgen therapy was given through an anterior and a posterior field; the cumulative skin dose (anterior plus posterior fields) was 9,940 r in 40 days. Marked symptomatic improvement was already noted after 2,000 r had been delivered at which point the tumor mass had decreased in size by about 40 per cent. By the time the treatment was completed the patient was asymptomatic and the tumor had almost disappeared.

Four months later, although the patient had no complaints, endoscopic examination revealed a tumor mass in the middle and upper thirds of the trachea, which showed some extrinsic deformity probably due to enlargement of a left mediastinal lymph node. The area previously irradiated, however, showed no signs of local recurrence. A new series of roentgen therapy was started, delivering 3,900 r to each of two anterior ports and 7,200 r to a single posterior port in 56 days. The patient has remained asymptomatic up to the present time, two years after the diagnosis was established.—*F. Comas, M.D.*

Vermooten, Vincent, and Maxfield, J. G. S. The use of radioactive cobalt in nylon sutures in the treatment of bladder tumors: Technique and case reports. *J. Urol.*, Dec., 1955, *74*, 767–776. (Address: Dr. Vermooten, 2609 Welborn St., Dallas 4, Texas.)

Radioactive cobalt in nylon sutures has many advantages over the previous methods of application of interstitial radiation in carcinoma of the bladder. The nylon tube suture containing the radioactive cobalt is soft and flexible and through a suprapubic exposure one can tell exactly where it is placed. It will follow the contour or shape of the bladder and each suture can be placed approximately parallel and equidistant. Since the tumor can be at least partially removed so that there is approximately 1 cm. thickness to the bladder wall, it is entirely possible to irradiate the entire tumor area with a homogeneous type of biologic effect. This method of irradiation is not used by the authors in those patients with multiple papillomas or small noninfiltrating lesions. It is reserved for those patients with solitary infiltrating lesions in which segmental resection would be inadequate and those in which total cystectomy would normally be done.

The operating team is protected during the entire course of the procedure from stray radiation. The lead-shielded container holding the radioactive material is placed on a table as close to the operative site as possible. Long nylon leaders are sutured into their proper relationships and only after the sutures are in their desired position is that portion of the suture containing the radioactive cobalt pulled from the lead safe and placed into position in the bladder wall. The bladder and abdominal wall are closed and the nylon sutures are brought out through the skin on either side of the incision, in such a way that they can be localized for future shifting following a roentgenogram of the implantation. In order to separate the bladder walls a 30 cc. balloon attached to a urethral catheter is placed in the bladder.

The radioactive material of cobalt wire is cut to form cylinders measuring 3.0 mm. in length and 0.5 mm. in diameter. Each piece of cobalt 60 has that amount of radioactivity necessary to produce 2.5 r per hour at 1 cm. distance. Each cylinder is then placed into a nylon tube and separated from one another by aluminum spacers of the same size. Radioactive cobalt is generally homogeneous and the small amount of beta radiation produced is filtered out by the nylon. This makes a soft and pliable scar even in those areas where the material has been placed adjacent to the ureteral orifices. The radiation pattern is planned to be left in place for seven days for an estimated dosage of approximately 7,000 gamma r to the tumor.

At the time of publication the authors had treated ten patients by this method. Three patients have died and seven are clinically well and cystoscopically free of tumor.—*George W. Chamberlin, M.D.*

Murphy, John J. The management of some late complications of pelvic irradiation. *J. Urol.*, Dec., 1955, *74*, 780–788. (From: Department of Surgery, Division of Urology, Hospital of the University of Pennsylvania, Philadelphia, Pa.)

The author submits 6 cases as evidence in favor of ureteroileostomy as a procedure of choice for the late complications of pelvic irradiation. He notes that previous operations such as nephrostomy, ureterostomy and ureterosigmoidostomy in this group of patients have had definite disadvantages chiefly due to the likelihood of renal infection following these procedures.

The author recommends an isolated segment of the ileum about 12 to 14 inches long be anastomosed to one or both ureters so that there is no tension at the site of the anastomosis. The distal end of the loop of ileum is brought to the skin surface in the right lower quadrant of the abdomen and the mucosa is sutured to the skin edge. The proximal end of the isolated segment is closed with sutures. The clinical course and pyelographic follow-up of all patients in whom the segment of the ileum has been used as a urinary conduit has been very satisfactory. The patients have been very satisfied with their ileostomy and find that the ileostomy bag can be made safe from leaks and easy to manage. This procedure apparently produces less electrolyte disturbance and hyperchloremic acidosis due to absorption of the urinary constituents than other procedures of the similar type.

Fifteen roentgenographic reproductions and two drawings illustrate the article.—*George W. Chamberlin, M.D.*

Fabian Bachrach photo

MERRILL C. SOSMAN

Editor

1947–1949